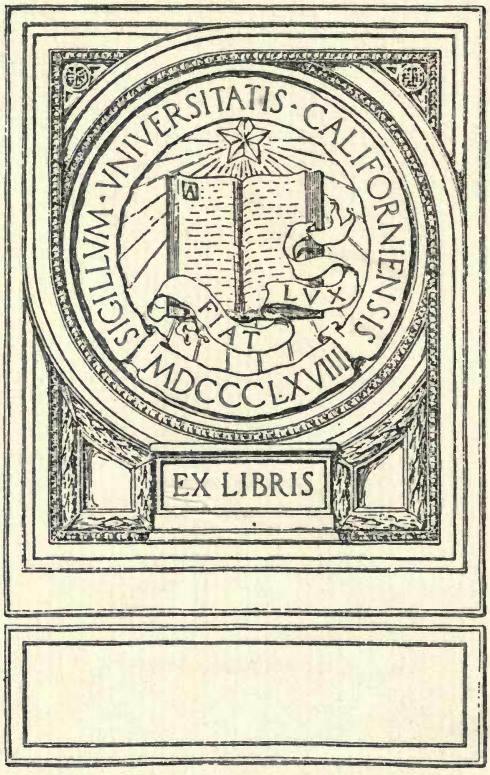
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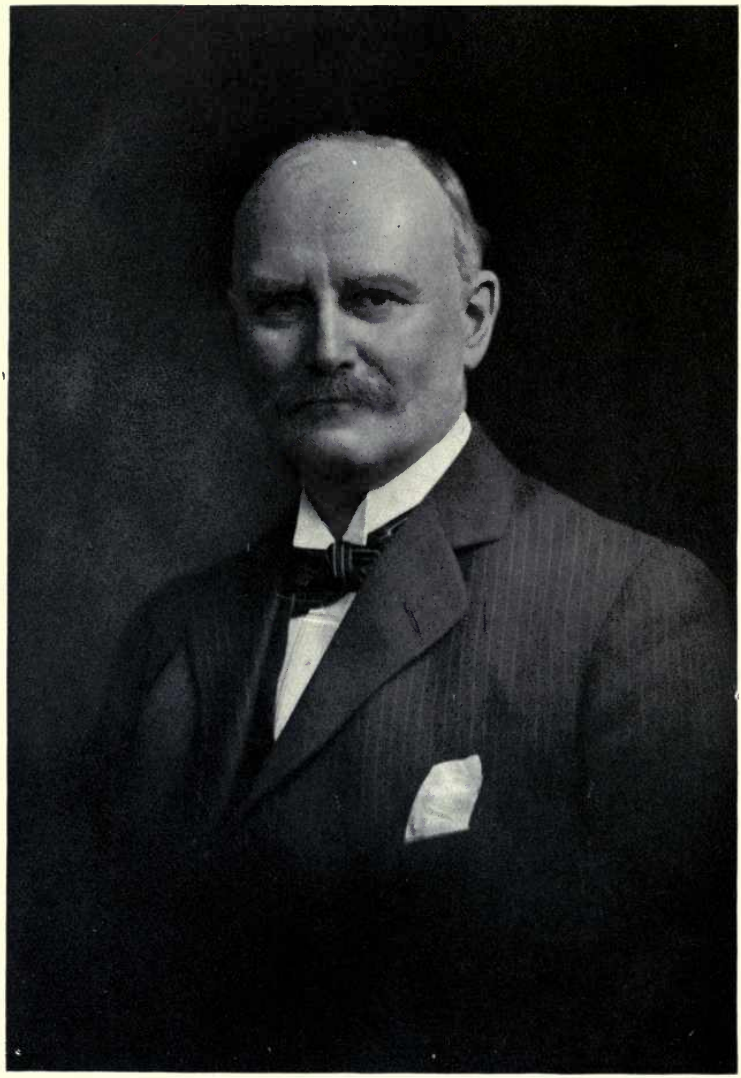
THE IRON AND STEEL INDUSTRY OF THE UNITED KINGDOM UNDER WAR CONDITIONS.



SIR JOHN HUNTER, K.B.E.

Director of Iron and Steel Production.

THE IRON AND STEEL INDUSTRY OF THE UNITED KINGDOM UNDER WAR CONDITIONS.

A RECORD OF THE WORK OF THE IRON AND STEEL PRODUCTION DEPARTMENT OF THE MINISTRY OF MUNITIONS.

BY

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PAST-PRESIDENT OF THE INSTITUTION OF MINING AND METALLURGY.

WITH ILLUSTRATIONS AND DIAGRAMS.

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PREFACE.

On account of the vastness of the field covered, the variety and complexity of the technical problems involved and the far-reaching industrial questions raised, the war activities of the Iron and Steel Production Department of the Ministry of Munitions form a subject of surpassing interest and importance. When, therefore, I was asked by Sir John Hunter to write an account of the work of that Department I gladly consented. Its records constituted an ample reservoir on which to draw for material, and every possible assistance in the work of compilation was given me by the heads of the different sections of the Department. Their names appear in the appropriate chapters.

From an historical point of view the narrative falls naturally into two divisions: first, that of the small Steel Department which was first formed as a branch of the Materials Department, of which Sir Leonard Llewelyn was Director, and second, that of the much larger organization formed by Sir John Hunter when he became Director of Iron and Steel Production in August, 1916.

In assuming this direction Sir John Hunter was confronted by a difficult task. The demand for steel for munitions and for shipbuilding was growing rapidly, while the supply of the raw materials essential for its manufacture was, by the activity of the enemy submarines, threatened with curtailment, if not with complete suspension, so far as foreign sources were concerned. The obvious remedy was the development of home resources. But the substitution of a lean phosphoric ironstone, such as constitutes the main portion of British iron-ores, for the rich ores

imported from abroad, involved such sweeping changes in plant, supplies, inland transport, labour, &c., that it could only have been carried out with difficulty even in peace time. Under war conditions it was evident that the problem would require the most skilful handling by a carefully organised department. I have endeavoured to show in the following pages that, in spite of difficulties which at times appeared to be well-nigh insuperable, Sir John Hunter's Basic Iron Programme obtained a high measure of success, and enabled the urgent and incessant calls of the great Service Departments for ship-plates, shells, and other munitions requiring steel in their manufacture, to be punctually and duly met.

It is a remarkable tribute to the latent organising power of the nation that, under the adverse conditions of a great war, it should have been possible to raise the steel production of the country to the highest point it has ever reached in the history of the industry. Under the stress of necessity, raw materials, that had been allowed to lie dormant in this country, were rapidly developed and brought to the producing stage. Ironstone in Oxfordshire, coking coal in Scotland, ganister for silica-bricks, moulding sands for foundry work, and refractory sands for open-hearth furnace bottoms, are instances in point.

I venture to suggest two main reasons for Sir John Hunter's success: first, the trust reposed by him in the members of his staff—a trust which, I may say, was entirely reciprocated; secondly, the fact that manufacturers, appreciating the position taken up towards them, cordially co-operated in the plans of the Ministry, and loyally concentrated on war work. Many firms readily fell in with the suggestions of the Department to depart from routine practice and to embark on experimental work, often at considerable financial loss to themselves. Material assistance was given in other directions by individual makers of iron and steel, particularly in placing their special knowledge at the disposal of the Department. Thus, for example, the manufacture of shell-steel was, at the beginning of the war, in the hands of a very few firms. The unprecedented demands

of the Army necessitated a sudden expansion of production; and, in bringing this about, the Ministry derived great assistance from the action of these firms in imparting to manufacturers, who were unaccustomed to this class of work, the technical details of processes of which they had unique knowledge. Others placed their designs for new plant at the entire disposal of their competitors. By such public-spirited action many firms undoubtedly rendered a great service to the nation, and have earned its gratitude.

F. H. HATCH.

14, Great Smith Street,
Westminster,
January 20th, 1919.

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EARLY HISTORY AND ORGANIZATION OF THE IRON AND STEEL PRODUCTION DEPARTMENT.

Early in June, 1915, the Cabinet decided to form a Ministry of Munitions to provide the large quantities of shells and guns required for the Army, and Mr. Lloyd George became the first Minister. In introducing to Parliament, on the 23rd of June, a Bill for furthering the efficient supply of munitions, Mr. Lloyd George explained that the whole of the Munitions Department, except the Section dealing with explosives, had been placed under the direction of Sir Percy Girouard. He also pointed out the urgent necessity of mobilizing raw materials and of having periodic returns made of the production of raw and semi-manufactured materials.

Before the formation of the Ministry the supply of munitions had been the work of the Armament Outputs Department (a small department of the War Office), which comprised Sir Percy Girouard, Mr. George Booth and Sir Eric Geddes. Lt.-Col. J. F. H. Carmichael was in charge of the Materials Section of this Department and also dealt with the release of men from the Colours to supply the needs of manufacturing firms engaged in war work. On the formation of the Ministry Sir Percy Girouard became Director-General of Munitions Supply with Sir Eric Geddes, Mr. George Booth and Sir Glynn West as Deputy Directors-General; but Sir Percy Girouard very soon resigned and was succeeded by Sir Frederick W. Black. Sir Leonard Llewelyn became Director of Materials and Lt.-Col. J. F. H. Carmichael was instructed by the War Office to join the Ministry as Assistant-Director to Sir Leonard.

The nucleus of the present Iron and Steel Department was brought into being by the appointment, on the 22nd of June, of Colonel W. Charles Wright, of Messrs. Baldwins Ltd., who was asked to supervise the supply of steel and the distribution of orders for steel. To assist him in this work he obtained the services of Mr. W. T. MacLellan in July, 1915, and of Mr. James Peech of Messrs. Steel, Peech and Tozer, in the beginning of August, 1916: the former to look after the requirements of the Allies, the latter to deal with the supply of shell-steel. It should be pointed out that Mr. W. T. MacLellan had already been assisting the Government before the formation of the Ministry of Munitions. At the request of Mr. Runciman he went in the first week of October, 1914, to the War Office, in an honorary capacity, to assist in obtaining supplies of iron and steel goods for the immediate equipment of the army; and until March, 1915, he was occupied with this work. It covered an extraordinarily wide range, including the provision of entrenching tools, soup-cans, mess-tins, saddlery, bits, spurs, etc. In addition to this work Mr. MacLellan assisted Major Hausser in placing contracts for French shell-steel, a duty which he continued to perform up to the end of the war. In the first week of April, 1915, he was also asked to assist Mr. George M. Booth in increasing the supplies of shells, there being an immediate and urgent enquiry for those of the 18-pounder, 4.5-in. and 6-in. types. In connection with this part of his work Mr. MacLellan went to Woolwich to prepare, for the information of the shell-makers, pamphlets describing in detail the methods of manufacture and giving particulars of the processes and temperatures needed.

In July, 1915, Mr. F. W. Harbord was appointed as Honorary Metallurgist to the Ministry and in September Mr. Frank Merricks joined as Honorary Mining Engineer, Mr. W. R. Lysaght, although appointed as Honorary Spelter Adviser to the Ministry, was consulted on many questions connected with iron and steel, and attended most of the conferences bearing on that subject.

Colonel W. Charles Wright, C.B.

Controller of Iron and Steel Production.

Facing p. 2.]

In September, 1915, a Section of the Raw Materials Department was formed to deal with high-speed and carbon tool steel and placed under the direction of Mr. H. B. Jacks. Early in December, 1915, Mr. John Hall was appointed to control supplies of steel (other than shell-steel) which had been dangerously reduced owing to the great increases made in the output of shell-steel while the total production of steel remained constant. At the end of December, 1915, difficulties with fuel-supply necessitated the formation of a Coal and Coke Section which was placed in the charge of Mr. P. G. Lewis.

On 16th February, 1916, Colonel Wright left the Department to return to military duties, and the Steel Section was then placed under the direction of Mr. W. T. MacLellan. In the spring of 1916 it was felt that the pig-iron position had become critical and Mr. B. Walmsley, who joined the Department in May, was asked to make arrangements for an improved supply. Mr. W. J. Jones joined the Department in the middle of 1916 to deal with the supply of refractory materials in which a shortage was beginning to make itself felt.

Early in August, 1916, a committee presided over by Dr. Addison decided that the Steel Section should be separated from Raw Materials and formed into a new department to deal with steel production, the Raw Materials Department being renamed the Non-ferrous Materials Supply Department. The new department was placed under the direction of Sir John Hunter, as from the 16th of August. Previous to taking over this direction Sir John Hunter had been Director of Factory Construction, a post that he assumed in October, 1915, at the request of Mr. Lloyd George, then Minister of Munitions, at the same time relinquishing the Managing Directorship of Sir Wm. Arrol and Company and other important interests. As Director of Factory Construction he was responsible for the erection of 17 large National Factories in London, Glasgow, Sheffield, Newcastle, Leeds, Nottingham and Lancaster and of other munitions factories and works.

In taking up his new duties as Director of Steel Production Sir John continued his direction of Factory Construction. In August, 1917, when Mr. Churchill formed the Munitions Council, Sir John was appointed Member of Council for the "S" Group, which then comprised the Departments of Iron and Steel Production and of Factory Construction. At a later date the Department of Forgings, Castings and Stampings, that controlling Building Bricks, and the Munitions Coal Supply were added. Although it does not actually fall within the limits set to the present historical statement it should be pointed out that, in addition to these heavy responsibilities, Sir John Hunter was appointed a Member of the Air Council and also took over the whole building programme of that Ministry under the title of Administrator of Works and Buildings.

At the time when Sir John Hunter became Director of Steel Production the following gentlemen were assisting the Department in various capacities: Mr. W. T. MacLellan (Deputy-Director), Mr. J. Peech (shell-steel), Mr. John Hall (steel other than shell-steel), Mr. B. Walmsley (pig-iron and limestone), Mr. P. G. Lewis (coal and coke), Mr. W. J. Jones (refractory materials), and Captain R. J. Wallis-Jones (iron-ore). Mr. F. L. MacLeod was appointed Official Adviser of Foreign Iron-Ore in September, 1916. Mr. F. W. Harbord continued to act as Consulting Metallurgist and Mr. Frank Merricks acted as Consulting Mining Engineer until the beginning of March, 1917, when a section was formed comprising himself and Dr. F. H. Hatch to stimulate the mining and quarrying of home iron-ore and limestone. Colonel Wright, who had been away from the Department since the 16th of February, 1916, and while away had visited Italy on a special mission for the Department regarding the supply of shell-steel for the Italian Army, returned to assist as Deputy-Director on the 2nd of January, 1917.

During the autumn of 1916, it had become apparent that, in order to meet the demands of the additional blast-furnaces it was proposed to operate for the production of basic pig,

it would be necessary to increase the supplies of ironstone and limestone. It was decided, therefore, that certain ironstone and limestone quarries, which had been reported as suitable for the purpose by Mr. Frank Merricks, should be taken over by the Ministry and worked by German prisoners of war. Camps for the accommodation of the prisoners were erected, and by the end of 1916 about 1,500 prisoners were at work.

By December it was evident that further steps were necessary if supplies were to be ensured against any possible development of the submarine menace. The position was undoubtedly serious ; the working stocks of hematite ore were much depleted and at some ironworks had practically disappeared, with the result that furnaces were entirely dependent on the arrival of shipments and several had to be put out of blast. It was decided, therefore, to undertake a more comprehensive survey of our iron-ore resources and with that end in view Mr. G. E. Stephenson was sent under Mr. Merricks' direction to the Midlands and to the Cleveland district. As a result of this enquiry Mr. Lloyd George was able to announce in the House of Commons on the 23rd of February that there were ample supplies of low-grade ore if labour could be found to work them.

A meeting was held in Dr. Addison's room on the 23rd of February to consider ways and means ; and as a result of this meeting Sir John Hunter was asked to take whatever steps he considered necessary for securing an increased production of iron-ore in the United Kingdom. He at once obtained the services of a number of mining engineers and of experts versed in the different branches of the iron and steel industry, with whom he formed sections of the Iron and Steel Department to deal respectively with the mining and quarrying of iron-ore and limestone, with the supply of fuel, refractory materials and labour, and with the reorganisation of both blast-furnaces and steel-furnaces. These measures were reported to Dr. Addison in a Minute dated the 7th of March, 1917.

The next step was the formation of a Committee on Home Iron Ore Supply with Sir John Hunter as Chairman, Colonel W. Charles Wright as Deputy Chairman, Major R. A. Laws as Secretary and the following members :—

A. K Reese C. G. Atha	to deal with basic pig-iron and steel production.
B. Walmsley	„ „ „ the allocation of pig-iron to steel furnaces.
F. Merricks F. H. Hatch	„ „ „ the mining and quarrying of iron and manganese ores and of limestone.
W. J. Jones	„ „ „ the supply of refractory materials.
P. G. Lewis	„ „ „ the supply of coal and coke.
T. M. McAlpine	„ „ „ the supply of mining machinery.
Major R. A. Laws	„ „ „ the supply of labour.
R. E. Palmer	„ „ „ transport.
F. L. MacLeod Capt. R. J. Wallis-Jones	„ „ „ foreign ore.
F. W. Harbord	to act as Metallurgical Consultant.

On Sir John Hunter's appointment as Member of the Munitions Council on the 20th of August, 1917, Colonel Wright became Controller of Iron and Steel Production and took over the Chairmanship of the Committee. Mr. Atha resigned from the Committee and from the Iron and Steel Department on the 5th of September, 1917, owing to pressure of work in connection with his General Managership of the Frodingham Iron and Steel Company. On May the 30th, 1917, the Labour Supply Section was taken over by Mr. A. C. Williams who also, on the 17th of April, 1918, became Secretary to the Committee on the transference of Major R. A. Laws to the Air Ministry.

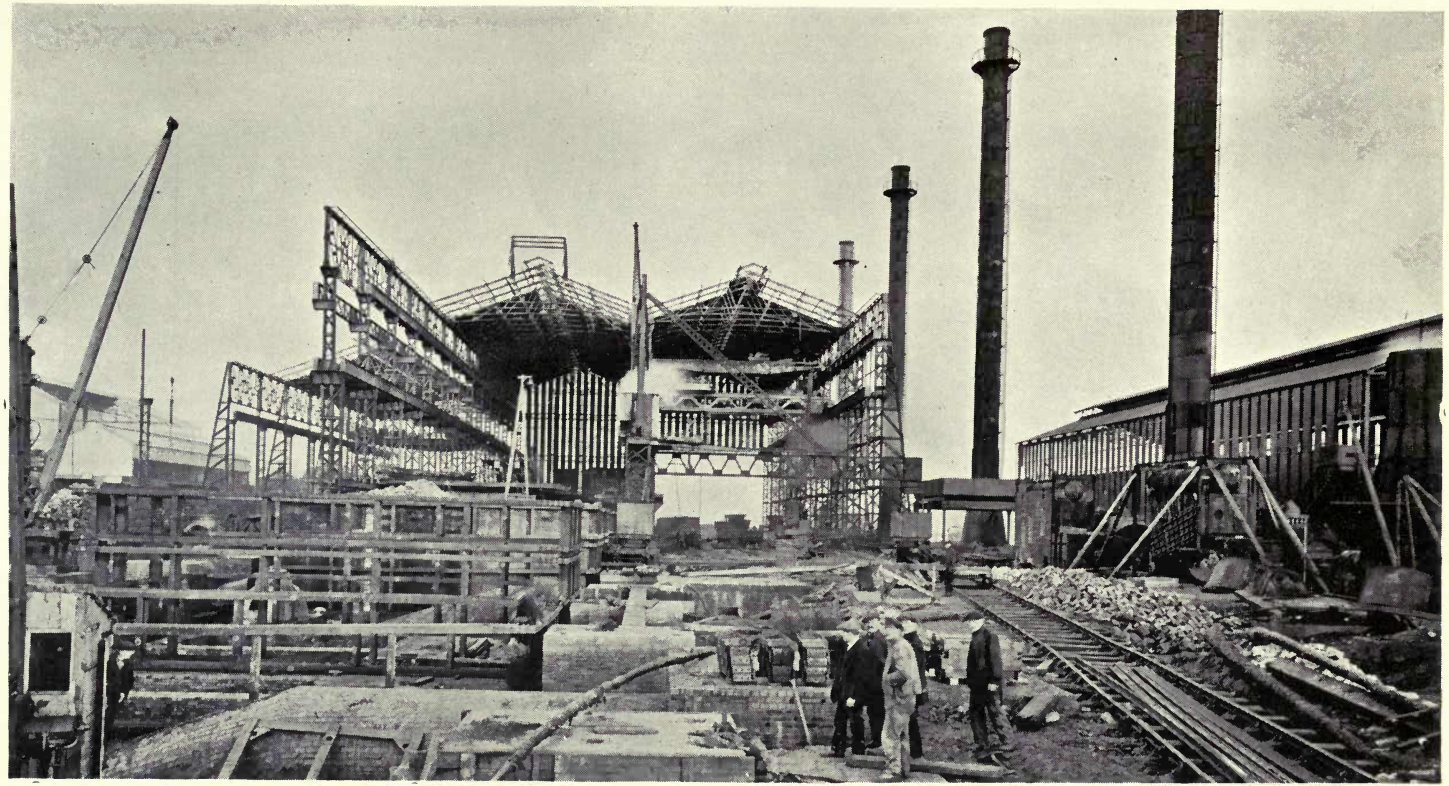

FIG. 1.—Extension to David Colville & Sons' steel works at Glengarnock, Ayrshire. New melting shop. (December 19, 1917.)

CHAPTER II.

SHELL-STEEL.

The most urgent question which the Steel Section had to face in the first instance was the supply of steel for shells, guns and other munition purposes, and in this connection it became necessary to fix the price of shell-steel. For this purpose a meeting of representatives of the leading steel firms of this country was called on the 29th of June, 1915, the Ministry of Munitions being represented by Sir Leonard Llewelyn, Colonel Charles Wright and Mr. W. T. MacLellan, and the French Government by Major Hausser and Captain Ziegel.

Eventually the following standard prices for shell-steel were agreed upon :—

For the British Government.—Rounds and billets (whether made from acid or basic steel) having a diameter of 3 to 6½ inches and a length of not less than 8 feet—£15 per ton f.o.t. the steel-maker's works.

For the French Government.—For 82 mm. bars, whether made from phosphoric pig in basic-lined open-hearth furnaces —£14 10*s.* per ton. If made from hematite pig in acid-lined open-hearth furnaces—£15 10*s.* per ton. For 75 mm. bars the above prices were increased by £1 per ton.

Since the prices ruling before these standard prices were fixed averaged £17 per ton, a considerable saving was effected by these measures. At the same meeting provisional arrangements were made to supply the shell-steel requirements of both British and French Governments.

It will be easily understood that the necessity of meeting the enormous demands which were being made by the

War Office threw a big strain on the Department. Prior to the war only five or six steel firms in this country had had any experience in the manufacture of shell-steel; moreover the War Office specifications were of a special character and required the steel to be made by the acid process. At the same time there was no standard method of making shells and every forgemaster and machinist had his own idea as to the size or section of billet or bar best suited for the purpose. In consequence it took considerable time and trouble on the part of Mr. Peech to get the various sizes and sections in use standardized for each calibre and to fix a standard weight for each type and mark of shell.

In view of the large demands of steel for high explosive shells it was soon recognised that it would be necessary to get the specifications revised; and after many weary months of negotiation permission was obtained in October, 1915, to use, under certain restrictions, both open-hearth and acid Bessemer steel. At a later date the use of basic steel was allowed and a large proportion of shells were made subsequently from this class of steel.

Many requests came forward from manufacturers asking permission to increase the percentages of phosphorus and sulphur in shell-steel made by the acid process. The percentage of phosphorus had already been raised from .04 to .05 in January, 1915, and a considerable amount of doubt existed as to how far it would be safe to allow still higher percentages, especially in view of the large amount of segregation which was certain to take place in the steel-ingots during cooling. In October, 1915, the Army Council notified their acceptance of a maximum of .06 for phosphorus and sulphur together, and in April, 1916, this was increased to .07 for shells of certain sizes. Without further information it was not considered safe to exceed these limits. On the recommendation of Mr. Harbord, therefore, the Ordnance Committee arranged for experimental work to be made on steel produced by the basic open-hearth, basic Bessemer and acid Bessemer processes. The steel was made to contain as nearly as possible 0.1 per cent. of phosphorus and of sulphur;

but some of the shells contained higher percentages that this, owing to segregation. As a result of mechanical and other tests and of a large number of firing trials it was found that steel containing up to .08 per cent. of sulphur and phosphorus was perfectly safe for shell-steel, and on the recommendation of the Ordnance Committee the specification was modified so as to permit steel containing .08 per cent. of sulphur and phosphorus to be used for high explosive shells for land service. It was not considered necessary or desirable to allow a higher percentage than this as a specification limit, since, although .1 per cent. of these impurities might have been permissible, it was impossible to ensure that this would not be considerably exceeded on account of variations in the same cast arising from segregation. In any case the output would not have been materially increased by allowing this higher figure, since any slight advantage that might have been obtained would have been more than outweighed by the losses caused by unsound material.

Owing to the fact that the majority of the steel-works were inexperienced in the manufacture of shell-steel, there was at first a large amount of rejections on account of surface flaws, etc. The steel manufacturers had mostly been accustomed to the manufacture of mild qualities of commercial steel, and it took some time to get produced a steel suitable for the manufacture of shells. Considerable help in the matter was obtained from those makers who had been accustomed to make shell-steel previous to the war; and an important use was made by the Ministry of the technical staffs of these makers. Valuable assistance was given also by the French Technical Department who, working on the same lines as the Steel Department, had improved the quality of shell-steel. It was also found that a considerable number of shells were being condemned owing to the margin allowed for turning them to the finished size being insufficient, and the following changes were made:— The margin was increased for 13-pounder shells from $3\frac{1}{2}$ to $3\frac{5}{8}$ inches; for 4.5-inch shells from $4\frac{3}{4}$ to $4\frac{7}{8}$ inches; and for 6-inch shells from $6\frac{1}{4}$ to $6\frac{1}{2}$ inches.

In view of the increase in the demand for shell-steel early in 1916, and the necessity for putting more British works making shell-steel on to steel sections, which were in very short supply owing to the requirements of the new factories then under construction, it was decided to get assistance from America ; and Mr. C. G. Atha, who had a great knowledge of the manufacture of steel in this country, went to the United States in June, 1916, to arrange for the required supply. At first progress was slow ; only in the largest works could the necessary quantities of shell-steel be obtained ; in America such works are built and organised for a large production of a definite class of steel, and any fresh departure at once caused difficulties varying in each case according to the particular nature of the normal output. Much technical discussion and explanation were required before either plant or methods could be adapted to the necessities of shell-steel manufacture. This steel requires greater attention to the details of melting, casting and rolling, in order to ensure soundness of the material, than is the case with ordinary commercial steel, such as was the normal product of the American works. It proved impossible in many cases to adopt the rather elaborate methods necessary for the best results ; but by compromise a dependable article was ultimately produced, without the output being restricted to a prohibitive degree. Some difficulty was experienced in persuading American manufacturers to accept the onerous conditions as to inspection and testing called for by specification ; but these difficulties were ultimately overcome. Within three months of Mr. Atha's arrival the first shipments were made ; and up to the present time over one and a half million tons of shell-steel have been obtained from this source.

Since one of the clauses in the specification for shell-steel requires that, except in the case of shells turned from the bar (18-pounder high-explosive and below), all billets or bars must be broken to shell-lengths, in order to ensure soundness on inspection, it became necessary to erect special billet-breaking plants to deal with material coming from

overseas. The chief of these was erected at Trafford Park, Manchester, close to the Ship Canal, by means of which the steel could be brought by water from Liverpool. Similar plants were established at the Wolverhampton Corrugated Iron Company's works, Ellesmore Port, at the Great Eastern Railway Company's works, Stratford, and at the National Projectile Factory, Lancaster. Special arrangements were made for receiving the steel and dispatching it to the various plants in proportion to their capacity. The steel-breaking plant at Manchester, which was under the direct management of the Ministry of Munitions, with Mr. John Meighan as local General Manager, covered an area of 45 acres, of which five acres were occupied by buildings; and there were eight miles of railway and sidings. From these works sufficient billets were dispatched to the forgemasters and National factories in one week to make 150,000 shells of all sizes, from 18-pounder to 9.2-inch.

The shell-steel coming from overseas and requiring to be handled at the various works has averaged 14,000 tons per week, the total quantity dealt with since the establishment of the plants being over one and a half million tons. The weekly delivery was distributed to the different works in the following proportions :—

Works.	Output of Broken Billets in Tons per Week.
Trafford	7,000
Wolverhampton Corrugated Iron Co. ...	3,000
Great Eastern Railway Co., Stratford ...	2,000
National Projectile Factory, Lancaster ...	1,000

In addition to the above, 1,000 tons per week of overseas shell-steel was broken and forged by various firms in Scotland.

The production of shell-steel ultimately reached enormous dimensions, as shown in the Table of Deliveries given below. At one time nearly a third of the ingot output of this country was going into shell-steel.

If labour had been forthcoming for the extensions to iron and steel works which had been projected, and to provide the fuel necessary to operate new furnaces, the whole of

the demands for shell-steel would have been met at home, without having to go to America, with all the disadvantages and financial loss this entailed.

One interesting feature of shell-steel production during the war is the great improvement it has caused in the general quality of the steel manufactured throughout the country. This is a consequence of the superior methods adopted in order to ensure a high quality steel being supplied to shell-makers.

DELIVERIES OF SHELL-STEEL (IN TONS).

Year.	High Explosives and Shrapnel in Great Britain (excluding imports).	Imports.	Total Deliveries in Great Britain for Land Service and Admiralty.	Deliveries to Allies.	Total Deliveries.
1915	145,900	Nil	145,900	63,269	209,169
1916	1,145,798	76,197	1,221,995	570,190	1,792,185
1917	1,218,191	588,490	1,806,681	528,031	2,334,712
1918*	877,971	600,752	1,478,723	117,494	1,596,217

* Up to November, 30.

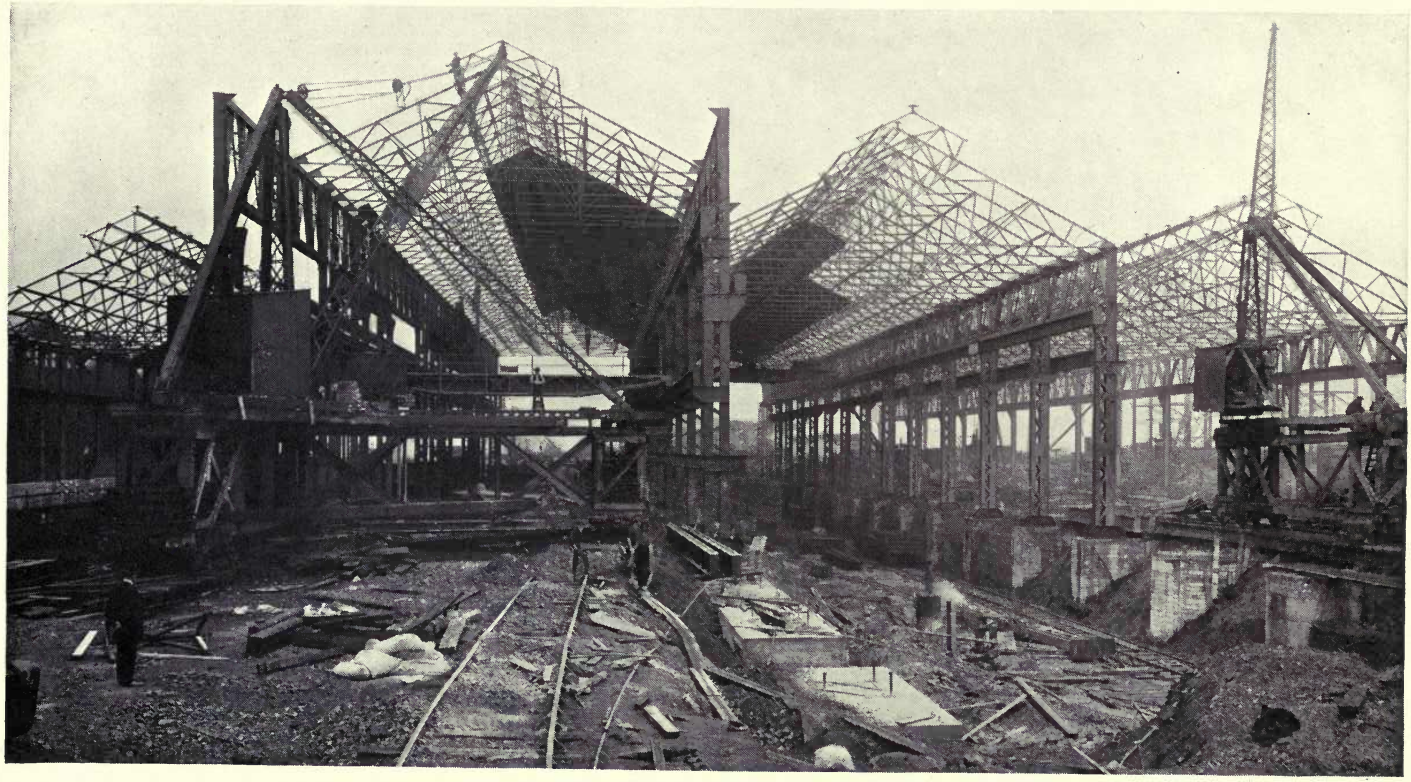

FIG. 2.—Extension to William Beardmore & Co.'s steel-works at Mossend, near Glasgow. New melting shop and rolling mills. (Aug. 17, 1916.)

CHAPTER III.

STEEL OTHER THAN SHELL-STEEL.

At the formation of the Steel Section and until about twelve months afterwards, Mr. Benjamin Talbot and Mr. Scoby Smith kindly gave their services in an advisory capacity. Mr. Talbot prepared a useful statement which gave the number and types of furnaces at each steel-works, the weekly output of ingots, with their quality, weights and sizes, and a classification of the rolling mills. Its object was to show what possibility there was of increasing the output of shell-steel.

For some time the work of the Steel Section was limited to the control and distribution of the steel required for the manufacture of shells; but when, in consequence of the transfer of a number of works from their normal production to the manufacture of shell-steel, a shortage of steel used for general purposes began to make itself felt, it was deemed advisable to control the distribution of all available supplies, and Mr. John Hall was invited to join the Steel Section to carry this policy into effect.

Early in 1916 prices commenced to rise rapidly, and it became apparent that it would be necessary to fix the prices, not only for steel, but also for the raw materials used in its manufacture. Conferences were, therefore, held with the owners of the hematite iron-ore mines, and with the manufacturers of pig-iron, coke, bricks, etc.; finally, maximum prices were fixed for all these commodities, and published in the *London Gazette* of the 2nd May, 1916.

Towards the end of 1916 it was recognised that in view of the short supply it would be necessary to bring the whole

of the steel output under control, and a joint scheme was therefore arranged between the Priority Branch and the Steel Department, under which the purchase and delivery of steel was prohibited, unless previously a priority certificate had been obtained from the Priority Branch. A general Order, entitled " The Control of Steel Supplies," was therefore issued on 20th November, 1916, and the Steel Department called for returns for each individual item of all steel deliveries. This enabled the Department to ensure that the priority certificates were being correctly used and that actual war orders dealt with in the order of urgency. With this information in hand it was an easy step to tabulate a statement showing the amount of steel delivered to each Government Department as well as for all other purposes. The whole output of steel was covered, whether for home supply or export. To ensure that urgent orders were completed before the rolls were taken out, the firms were also asked to furnish " rolling programmes " by means of which it was possible to make timely rectification of any such errors. Furthermore, particulars of all iron and steel stocks held in the country were required to be furnished monthly in order to enable the Steel Department to requisition any material required for urgent work. Steps were also taken to distribute orders in such a manner as to avoid frequent change of rolls, and to place each firm in a position to concentrate on the particular sections best suited to their mills.

The first step taken to deal with export was to prohibit the rolling of any steel for shipment, without a licence having first been obtained from the Steel Section. Later on steel for export was put on the prohibited list and the issuing of licences was transferred to the War Trade Department. Finally it was controlled by the general " Steel Order " mentioned in the preceding paragraph.

In course of time it was found that the re-rolling firms could not produce all the finished steel required owing to the shortage of semi-manufactured material. This necessitated the supplies of these materials being controlled and

ultimately the allocation of the whole output to the firms requiring it.

In July, 1917, the continued shortage of steel necessitated further steps being taken to ensure an equitable distribution. Each department was therefore asked to furnish monthly its steel requirements for the ensuing month. These figures were then put together, and at a meeting of the departments concerned, the demands were scrutinised and the respective tonnages adjusted to fit the output. The final system of control developed into an allocation of certain finished materials to those services to which it was absolutely essential, and the delivery of the rest of the steel according to the priority allocated.

In connection with this allocation scheme the country was divided up into six areas with a committee of the local steel-makers in each, to work with, and to give assistance to, the Ministry. At the same time the officer charged with the inspection of steel for the Admiralty, became Steel Superintendent, working equally for the Admiralty and the Ministry of Munitions. This arrangement was made, in order to ensure that all Government departments obtained their fair share of whatever material was available.

High-Speed and Carbon Tool Steel.

The supply of high-speed and carbon tool steel was from the start dealt with by a Section under Mr. H. B. Jacks with Mr. O. Sewell to assist him. This Section has controlled the supply of these materials to the National factories, to munition works, and to contractors as well as to our Allies. In February, 1916, a committee of high-speed steel manufacturers and manipulators was formed in Sheffield. This committee undertook to see that there was no shortage of tool-steel for munition work, and, under the ægis of the Section, allocated all orders for this material. The supply of tungsten to high-speed steel manufacturers was also allocated. The committee did its work with great success, and since its inception all requirements, both at home and abroad, were duly met. At the time of its formation from 6,000 to 7,000 tons of

high-speed steel were being produced per annum, whereas in 1918 the output was from 18,000 to 19,000 tons per annum.

In order to induce firms using Swedish bar-iron for the manufacture of tool steel to try home material, Mr. Harbord made arrangements with five or six of the leading Sheffield steel manufacturers to make sets of tool steel bars from material specially low in phosphorus and sulphur. The steels were made by melting in crucibles—(1) "Armco" iron, (2) specially selected dead soft basic steel, and (3) for comparison, the best Swedish materials; in each case ingots were made from both "cemented" and "uncemented" bars. The ingots, after forging down, were sent to the Sheffield University, there forged into turning tools, and a systematic investigation made of their cutting properties, before and after repeated forging.* The results obtained from the British materials were equal to those from the Swedish material, and since then a considerable quantity of the home materials have been used as a substitute for Swedish bar in the manufacture of both carbon and high-speed tool steels.

ALLOY-STEELS.

In July, 1917, owing to the enormous increases in aircraft, the question of the supply of alloy-steels became urgent. The Air Board was then obtaining some 800 tons per month of these materials from the makers, which in no way met their demands. After consultation with Colonel Alexander, of the Aircraft Production Department, it was decided to form an Alloy-Steels Production Committee in Sheffield, with functions similar to those of the High-Speed Tool Steel Committee. The Committee was formed at a meeting held in Sheffield on the 26th of July, 1917, which was attended by representatives of all the principal makers of alloy-steels; the specific duties allotted to it were to assist the Ministry in providing the required supplies of alloy-steel for all

* *See* Report on Carbon Steel Tools, made from British and Swedish materials for the Ministry of Munitions. Tested in the Engineering Laboratories of the Sheffield University by W. Ripper, Professor of Engineering, May, 1917.

purposes, including aircraft, tanks, mechanical transport, guns, Admiralty, etc.

The Committee held its first meeting on the 22nd of August, 1917, under the chairmanship of Mr. Bernard Firth, and went to work in the most business-like manner. By persuading firms, without any previous experience in this class of steel, to undertake its manufacture, and by giving assistance both in regard to specifications and practice, it raised the quantity of the alloy-steels supplied to the Air Board to approximately 4,000 tons per month by Christmas, 1917, and by May, 1918, to close on 6,000 tons per month. The Aircraft Production Department then discovered that they had over-estimated their immediate requirements, and finding there was a stock of some 10,000 tons of these steels in store, it requested the Steel Department to reduce the output. Although a great many firms were hard hit by this curtailment of their orders, the Committee was successful in persuading manufacturers that it was in the interests of the country that this step should be taken.

In September, 1917, an inter-departmental Alloy-Steels Committee was formed upon which the Steel Department, the Aircraft Production Department, the Mechanical Warfare Department, the Mechanical Transport Department and the Controller of Forgings and Castings were represented, other departments requiring alloy-steels also being at liberty to send representatives. Through this Committee all allocations to the various departments were made, a record being kept of deliveries against demands. This Committee did some useful work in the investigation of complaints especially in regard to the supply of steel for drop-forgings.

Production of Steel, including Shell-Steel, during the War Period.

Figures for the annual production of steel of all kinds during the period 1913–1918 (inclusive) are given in Chapter XVII, p. 120. The following analysis of the 1918 production, made by Mr. R. C. Rann from returns made to the Iron and Steel Department, will be of interest, as showing the

quantity of acid and basic steel respectively produced by each process of manufacture.

ANALYSIS OF STEEL OUTPUT IN 1918.

	Ingots.	Castings.	Total.
Acid—			
Open-hearth...	3,880,949	103,731	3,984,680
Converter	754,899	48,858	803,757
Electric	78,791	46,657	125,448
Stock converter	643	13,075	13,718
Tropenas	10,870	53,633	64,503
TOTAL ACID	4,726,152	265,954	4,992,106
Basic—			
Open-hearth	3,986,269	9,899	3,996,168
Converter	550,500	665	551,165
TOTAL BASIC	4,536,769	10,564	4,547,333
TOTAL ACID AND BASIC	9,262,921	276,518	9,539,439

Of the total output of steel in the year 1918, 51 per cent. was produced by the acid process and 49 per cent. by the basic process. It will be noted, moreover, that for the first time in the history of British steel-making, the output of steel made by the basic open-hearth process exceeded that made by acid open-hearth. During the last quarter of the year, the make of basic steel slightly exceeded the total make of hematite steel by all processes, the respective figures for the average weekly output during the quarter being: acid—85,468 tons per week, and basic—86,122 tons per week.

The table on p. 19 gives the production of steel by areas from the middle of 1917 to the end of 1918.

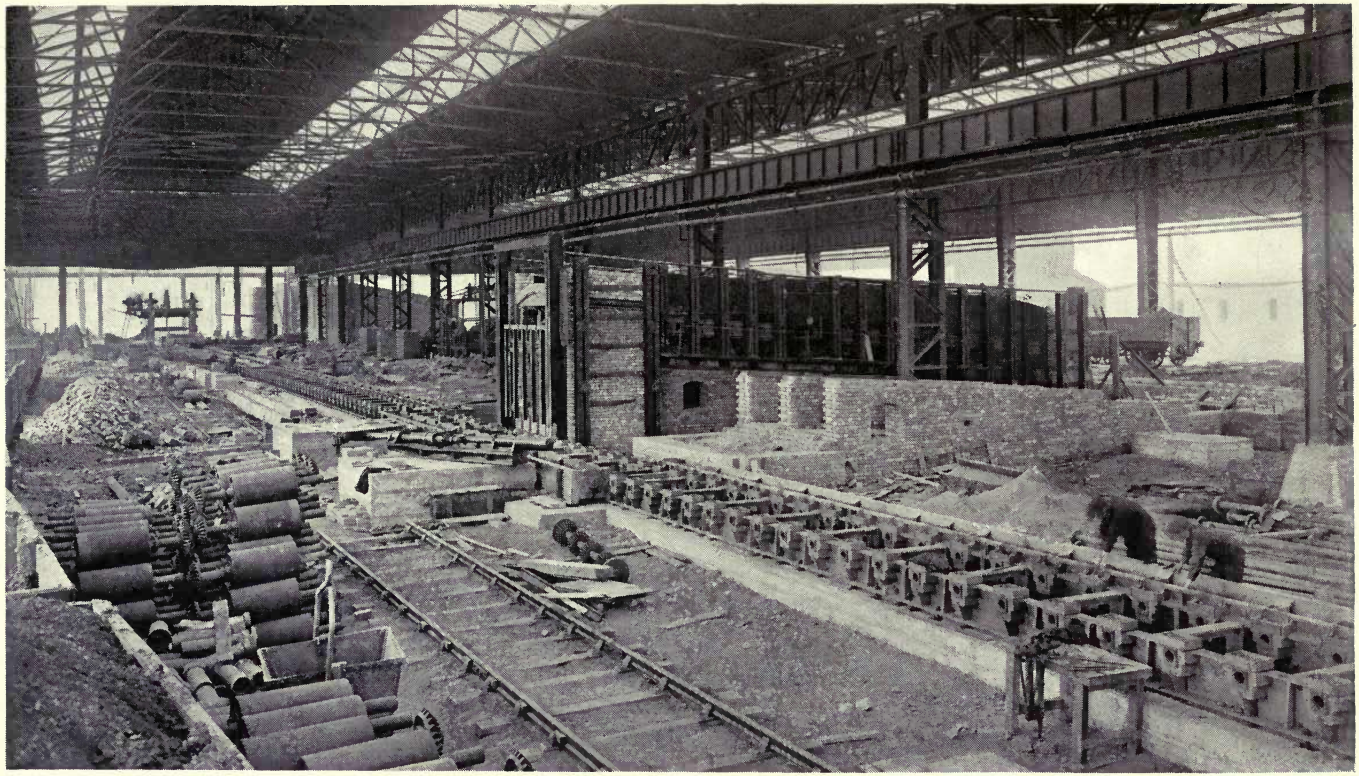

FIG. 3.—Extension to Bolckow, Vaughan & Co.'s steel-works at South Bank, near Middlesbrough, showing cogging mill, roller-gear and re-heating furnaces.

PRODUCTION OF STEEL IN THE UNITED KINGDOM BY AREAS.

	1917.		
	1st Half Year.	2nd Half Year.	Total.
North-East Coast	—	1,067,100	—
South Wales	—	1,079,695	—
Scotland	—	916,340	—
Sheffield	—	912,906	—
North-West	—	608,639	—
Midlands...	—	269,297	—
Total United Kingdom ...	4,862,567	4,853,977	9,716,544

	1918.		
	1st Half Year.	2nd Half Year.	Total.
North-East Coast	1,088,265	939,292	2,027,557
South Wales	1,044,715	1,024,227	2,068,942
Scotland	997,335	946,928	1,944,263
Sheffield	927,202	814,364	1,741,566
North-West	655,660	546,760	1,202,420
Midlands...	286,877	267,814	554,691
Total United Kingdom ...	5,000,054	4,539,385	9,539,439

Noteworthy are the increases in all districts, except South Wales, for the first half of 1918, and the falling off during the last half of the same year.

CHAPTER IV.

PIG-IRON, FERRO-ALLOYS, SWEDISH PIG, SWEDISH BAR, SCRAP.

When war broke out considerable stocks of pig-iron were held by the makers. This was the result of a fall in steel production, brought about by the importation of large quantities of German and Belgian steel during the twelve months immediately preceding the commencement of hostilities.

Up to June, 1916, these accumulations of all kinds of pig-iron enabled the excess of consumption over production to be met; but subsequent to that date stocks became depleted to a dangerous point, and Mr. B. Walmsley, who had joined the Department in May, 1916, to assist in the increased production of pig-iron, decided, after reviewing the hematite pig position, that a fair distribution could only be ensured by allocating the output. In July, 1916, therefore, the supply of hematite pig-iron was brought under control, and the whole of the output allocated to consumers month by month. In May, 1917, this system was extended to basic pig-iron, and since that date all steel-making iron has been allocated monthly. Mr. P. Fernihough assisted Mr. Walmsley in this work, and continued it when Mr. Walmsley became Director of Iron and Steel Contracts.

In June, 1916, Mr. Walmsley formulated a programme for bringing into operation additional blast-furnaces. The table published by him in June, 1916, included 51 additional furnaces to come into blast by the end of 1918. Of these only 10 were new furnaces. Of the remaining 41, some

required additional plant to enable them to be operated, others had to be re-lined and repaired. The production of these 51 furnaces was estimated at 38,120 tons per week, namely: hematite, 19,050 tons per week; basic, 19,070 tons per week, or in all about 1,900,000 tons per annum.

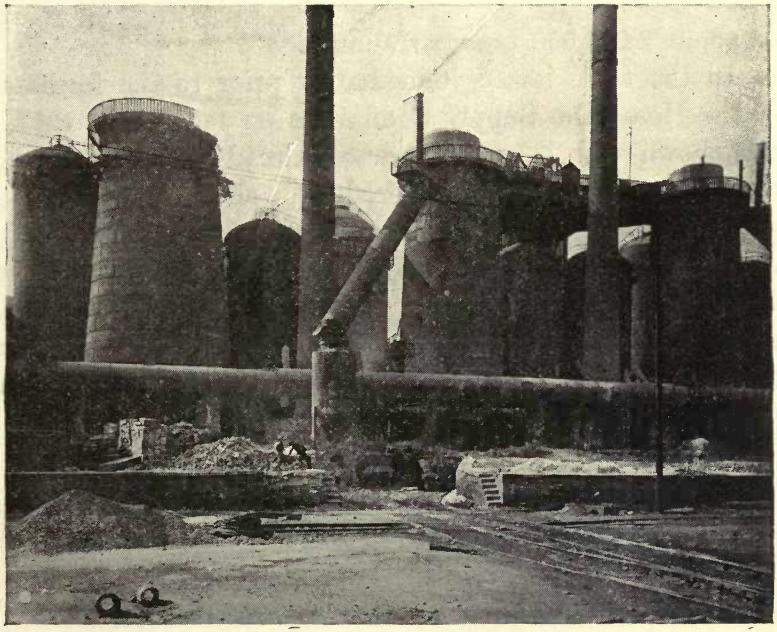

FIG. 4. Extension to the Tees Furnace Co.'s Lackenby Ironworks at Grangetown. New Blast Furnace on the left of photograph. (October 4th, 1917).

In the second table, issued at the end of September, 1916, it was shown that 16 of these furnaces were already in blast, and producing 9,000 tons per week, or, say, 450,000 tons per annum. Almost the whole of this was hematite. The new table showed that, at that date, there were 57 additional furnaces to come into operation. This number included a further 10 new furnaces, making in all 20 new furnaces up to that date.

The 57 furnaces were estimated to produce the following quantities of pig-iron :—

	Tons per week.
Hematite	25,680
Basic	14,600
Cleveland Foundry and Forge	3,850
Foundry	900
Ferro-manganese	500
	45,530

or about 2,276,000 tons per annum.

In the table issued immediately prior to the formation of the Home Ore Supply Committee on 1st March, 1917, it was shown that 33 of the furnaces already arranged for had come into blast, and were producing about 18,000 tons of pig per week, or about 900,000 tons per annum. About one-quarter of this quantity was made up of basic and Cleveland iron. It was shown in this table that there were still to come into operation 56 additional furnaces, which were estimated to produce the following quantities :—

	Tons per week.
Hematite	27,300
Basic	21,500
Cleveland Foundry and Forge...	2,200
Foundry	1,000
Ferro-manganese	500
	52,500

or about 2,625,000 tons per annum.

The total number of furnaces arranged for up to this date was 89 ; and these were estimated to produce pig-iron at the rate of 70,500 tons per week, or, say, 3,500,000 tons per annum.

Unfortunately, owing to the restricted supply of imported iron-ore in the early part of 1916, it became impossible to complete the hematite programme, and it was decided to concentrate on the basic programme. The measures taken for this purpose are fully detailed in Chapter VII, page 43.

In order to keep pace with the increased steel-making capacity which resulted from the extensions to steelworks made at the end of 1916, and during 1917 large quantities of

pig-iron were imported from America. From October, 1916, to August, 1918, the import of hematite pig from this source amounted to 59,000 tons, and of basic pig to 145,000 tons. In addition to these imports, contracts for 180,000 tons of basic pig were placed in America for delivery during the last half of 1918. Of this amount about 74,000 tons have been delivered, and a further 20,000 tons are at the time of writing on the way. The balance has been cancelled.

Scotland.

The pig-iron position in Scotland was dealt with in a report prepared for the Iron and Steel Department by the Scottish Advisory Committee on Iron and Steel Production, and dated 24th December, 1917. This Committee consisted of Mr. Wallace Thorneycroft, of the Steel Company of Scotland; Mr. A. K. M'Cosh, of Messrs. William Baird & Company; and Mr. G. A. Mitchell, of Messrs. Stewarts & Lloyd, with Mr. F. Lobnitz, Director of Munitions in Scotland, as Chairman.

Of the pig-iron produced in Scotland, 65 to 70 per cent. is hematite pig made from imported ores. The balance is Scotch foundry and forge iron and basic, and of these makes only 30 per cent. is made from iron-ore raised in Scotland.

The preponderance of hematite is a development of the last quarter of a century. Previously, the pig-iron production of Scotland had been practically confined to foundry and forge iron, made from blackband and clay-ironstone mined in the Scotch coalfields, together with some imported hematite. The importation of foreign ore began about 50 years ago, and the proportion of this to native ore has been on the increase ever since. The amount of native ore now produced in Scotland is very small—somewhere between 300,000 and 400,000 tons per annum; and for many years, in addition to the importation of iron-ore, a considerable quantity of pig-iron of all sorts has been brought in from England, the bulk of which was Cleveland foundry.

Up to the end of 1916 the output of pig-iron, together with that imported from England, was sufficient to supply

the demands of the steel-makers in Scotland, and there was sufficient coal and coke to supply existing blast-furnaces. A quantity of pig-iron had been put in stock in bad times, and this was drawn upon to supply the extra demand arising from the acute pressure for steel in the latter half of 1915. But when the accumulated stocks of pig-iron began to be depleted, early in 1916, it became obvious that local production would not be equal to the requirements. Little, however, was done during the war to augment local production since it was apparent that the blast-furnace plant available was sufficient to smelt all the foreign ore that could be imported. On the other hand, the haulage, storage, and handling facilities at the blast-furnaces were improved, and machinery for expediting the dispatch of ships was provided at the docks, together with some small dumping accommodation at Rothsay dock on the Clyde. Some improvements were also made to the blowing-power and stove-capacity of the existing blast-furnaces, by which the liability of stoppage from breakdowns was reduced.

The maximum average weekly output of pig-iron of all kinds in Scotland during the war was 25,700 tons, in December, 1916, with an average of 85·3 furnaces in blast. The maximum output in any one week was 26,338 tons, with 86 furnaces in blast. The average weekly make per furnace was 300 tons, the range being from 240 to 670 tons per week. In December, 1916, 70 per cent. of the pig-iron production was hematite, for which imported ore was used in 62 furnaces.

At that time it was estimated that with the existing blowing plant six additional furnaces could be put into blast, making 92 in all, which at 300 tons per furnace would bring the weekly average up to 27,500 tons, or about 1,430,000 tons per annum. This was estimated to be the maximum possible increase in locally produced pig-iron with 92 furnaces in blast.

According to returns made to the Ministry of Munitions by the Scottish steel-makers, the consumption of pig-iron in December, 1916, averaged 22,262 tons per week, of which 19,062 tons was hematite (special and ordinary), and 3,200 tons, basic.

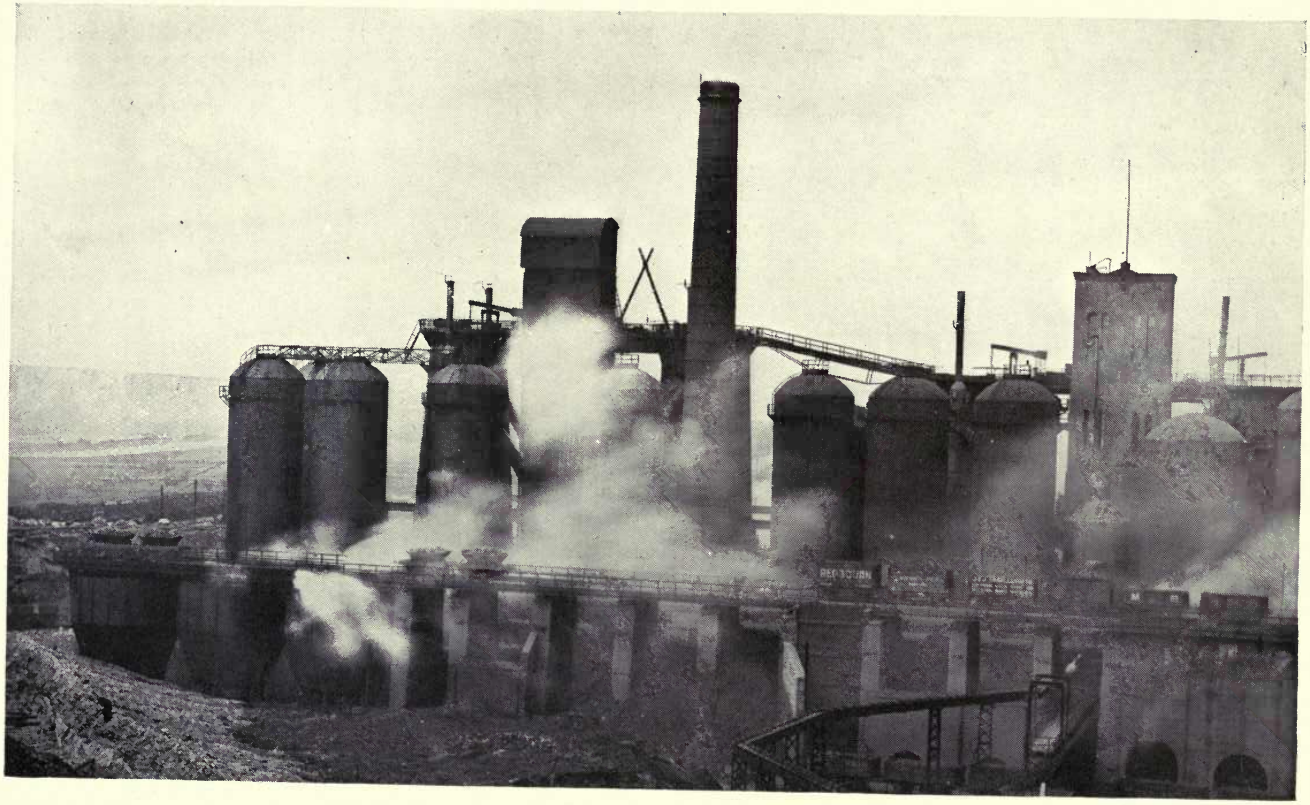

FIG. 5.—Extension to the Redbourn Hill Iron and Steel Co.'s ironworks at Scunthorpe, North Lincolnshire.

The extensions to Scottish steel-works now under way will require an addition of about 10,000 tons of pig-iron per week, making a total requirement of, say, 32,000 tons per week. The output of Scotch foundry and forge iron if maintained at the pre-war figure, say 15,000 tons per week, would make the total requirement of pig-iron 47,000 tons per week, of which, say, 23,600 is hematite and the remainder basic and foundry. For this 27 new blast furnaces would be necessary.

PRODUCTION, IMPORT, AND DISPOSAL OF PIG IRON IN SCOTLAND.

(On the basis of the maximum requirements for one year.)

Output and Imports.			Disposal.	
Output—	Tons, p. a.			Tons, p. a.
Hematite ...	900,000		Steelworks	1,550,000
Basic	100,000		Scottish foundries	550,000
Other makes	400,000		Export to English foundries	150,000
Total make		1,400,000	Overseas export	100,000
Pre-war Imports from England—				
West Coast Hematite	150,000			
East Coast Cleveland and Basic	500,000			
		650,000		
Additional Imports required—				
Hematite ...	100,000			
Basic	200,000			
		300,000		
		2,350,000		2,350,000

The production of pig-iron in Scotland during the war period is shown in the following table:—

PRODUCTION IN SCOTLAND DURING WAR PERIOD.

Year.	Hematite.	Basic.	Foundry.	Forge.	Other qualities.	Alloys.	Total.
1913	—	—	—	—	—	—	1,377,747
1914	—	—	—	—	—	—	1,125,967
1915	710,486	—	398,691	—	—	—	1,109,177
1916	798,196	—	346,570	—	—	—	1,144,766
1917	777,170	105,140	208,112	42,689	9,847	13,242	1,156,200
1918	639,080	92,871	295,619	44,291	5,106	8,433	1,085,400

It will be noted that there was a big drop in output in the year 1918. This was due to the difficulty experienced in importing hematite ore, and as a consequence it was the make of hematite which mainly suffered.

Cleveland.—The pig-iron required by the increased production of basic steel in the Cleveland district during the war was provided to a large extent by bringing into operation idle furnaces, or by changing over to basic, blast-furnaces previously making hematite pig and Cleveland foundry and forge iron. With the resumption of peace conditions, the production of acid steel and of hematite pig will probably revert to its former dimensions, but the increase in basic steel-making will to a great extent remain. Since the output of the Cleveland mines is not capable of any great expansion, the increased demands for basic iron may limit the production of Cleveland iron in the future. There is a possibility, however, that the situation may be relieved by bringing in phosphoric ironstone from the north-west of France.

The production of pig-iron of all sorts on the north-east coast during 1917 and 1918, compiled from returns made to the Ministry of Munitions, is shown in the following table:

PRODUCTION OF PIG-IRON ON THE NORTH-EAST COAST.

	1917. Tons.	1918. Tons.
Hematite	1,259,966	984,593
Basic	1,079,923	1,197,117
Foundry	545,888	497,855
Forge	176,060	172,906
Other qualities	27,466	14,633
Alloys	113,770	98,647
Total	3,203,073	2,965,751

North Lincolnshire.—Until comparatively recent times the pig-iron production of this district was entirely devoted to foundry and forge qualities. The development of the Siemens basic process of steel-making has, however, introduced a demand for iron low in silicon and sulphur, for which the Frodingham ironstone is peculiarly suited, and to-day a large percentage of the output is converted into steel. There

are six firms operating blast-furnaces at Scunthorpe, and of these three also have steel-works and consume the whole of their make of pig-iron. Some of the others are associated with steel-works, and consequently there is little Lincolnshire basic iron on the open market. The ironstone, although low in iron (average, 23 per cent.), is chiefly quarried on account of its great thickness, and is self-fluxing. The resources to be drawn on before mining is resorted to, are estimated by the Geological Survey at 162,000,000 tons.* Coke supplies are brought to the district from South and West Yorkshire coalfields. The following figures of production are compiled from returns made to the Ministry of Munitions :—

PRODUCTION OF PIG-IRON IN NORTH LINCOLNSHIRE in 1917 and 1918.

	1917. Tons.	1918. Tons.
Hematite	*Nil.*	*Nil.*
Basic	472,175	595,566
Foundry	12,269	13,441
Forge	13,098	24,337
Other qualities	21,905	17,065
Alloys	*Nil.*	*Nil.*
Total	519,447	650,409

North-West Coast.—The pig-iron production of this district is entirely hematite, made chiefly from local ores, although these are supplemented by considerable imports from Spain and the Mediterranean. There has been no change during the war, except that the average quality of the make has deteriorated to some extent, owing to the impossibility of selecting the ore as carefully as in normal times. There are two large steel-works in the district, at Barrow and Workington, respectively, which depend on local supplies of pig-iron. The surplus production of the North-West Coast blast-furnaces is sent to all parts of the country, and is largely used in the manufacture of special qualities of steel. The following figures of production on the

* Geological Survey: Summary of Progress, 1917.

North-West Coast are compiled from returns made to the Ministry of Munitions :—

PRODUCTION OF PIG-IRON ON THE NORTH-WEST COAST IN 1917 AND 1918.

	1917. Tons.	1918. Tons.
Hematite	1,168,533	1,195,424
Alloys	50,738	47,215
Total	1,219,271	1,242,639

South Wales.—The pig-iron production of South Wales is, to the extent of 80 per cent. of the total, hematite made from imported ore. As regards phosphorus content its quality is not equal to that made in Cumberland, partly because foreign ores are used, and partly because of the high phosphorus-content of the local coke. The whole of the pig-iron is consumed in local steel-works, but the output is not sufficient to meet the demand, and further supplies are brought into the district from the North-East and North-West coasts. The following figures of production in Wales are compiled from returns made to the Ministry of Munitions.

PRODUCTION OF PIG-IRON IN WALES IN 1917 AND 1918.

	1917. Tons.	1918. Tons.
Hematite	715,474	737,091
Basic	123,602	181,510
Foundry	524	457
Forge	226	265
Other qualities	225	13
Alloys*	78,013	38,889
Total	918,064	958,225

FERRO-ALLOYS.

On the formation of the Steel Department, the control of ferro-alloys was initiated by Colonel Wright, but it was subsequently taken over by Mr. W. T. MacLellan, who took the steps detailed below to keep the steel-makers supplied with these materials.

* All made at Darwen & Mostyn's, in North Wales.

In July, 1915, the principal shell-steel firms were asked whether they anticipated a shortage of ferro-silicon, and the replies tended to the belief that no difficulties would be encountered, provided the French supplies were continued; but on the 25th August, 1915, Messrs. Ridge, Beedle & Company, the agents of the principal suppliers of this material in France, notified the Ministry that their principals in France would probably not be able to furnish more than half the quantity contracted for with British firms. It was therefore arranged that Messrs. Ridge, Beedle & Company should purchase a supply in Norway.

On the 23rd September, 1915, Major Hausser informed the Ministry that the French Government had prohibited the export of ferro-silicon from France to Great Britain, and on Mr. Beedle attempting to make purchases in Switzerland on Government account, it was found that the French Government had already secured the chief supplies available. The French Government, however, agreed to allow the Ministry about 250 tons monthly out of their purchases from the Meteor Company.

To ease what was a difficult position in the ferro-silicon trade, the Darwen & Mostyn Iron Company, at the request of the Ministry of Munitions, entered into negotiations with Electro Metals, Limited, for the purchase of a supply. Since then the Darwen & Mostyn Company have purchased considerable quantities of ferro-silicon, and sold it to steel-makers in this country, acting as agents on behalf of the Ministry of Munitions. Purchases amounting to about 8,000 tons were also made from various sources on behalf of the Russian Government.

The stocks of ferro-silicon in this country at the conclusion of the armistice were equal to about three months' consumption.

In November, 1917, the Air Board informed the Ministry that they were extremely short of high grade 90 per cent. ferro-silicon. In order to assist the Air Board in this matter the Steel Department arranged to cancel orders placed in America for 5,000 tons of low-grade ferro-silicon, and to take,

in lieu thereof, high-grade material. At the same time, in order to assist the ferro-chrome position they arranged to place an order for 3,000 tons of low-grade ferro-silicon with a ferro-chrome manufacturer in Scandinavia. This policy, combined with the opportune arrival of sundry shipments on Russian account which were taken over by the Ministry, prevented any shortage, and at the time of the armistice the Air Board had something like six months' consumption of high-grade ferro-silicon in hand.

On the 12th June, 1915, a meeting was held with makers of ferro-manganese, when it was agreed that it would be advisable to keep at the steel-works stocks of ferro-manganese equal to about three months' supply, and at the works of the makers of ferro-manganese, stocks equal to three months' pre-war sales, plus a stock of manganese ore equivalent to three months' pre-war sales of ferro-manganese. The price for ferro-manganese had been fixed at £20 per ton. On the 3rd February, 1916, it was raised to £25 per ton on account of the increased freights, and on the 22nd January, 1918, it was again raised to £26 10s. per ton, at which price it remains at present. These figures are for home consumption; for export the prices have been kept open.

At a meeting held with the ferro-manganese makers in July, 1917, the supply of manganese ore for basic steel-furnaces was discussed. The considerable increase about to be effected in the output of basic pig-iron, and the fact that a large number of small buyers had come into the market, made it advisable to arrange for ferro-manganese makers to remain the sole importers of manganese ore, and for the incoming cargoes to be distributed to the basic steel-furnaces from centres convenient for quick transport.

The demands for manganese ore and the shortage of shipping resulted in our not being able to maintain fully the stocks at the figure originally aimed at; but at the conclusion of the armistice the combined stocks of manganese ore and ferro-manganese were equivalent to about six months' consumption in this country, without allowing for export.

The export of ferro-manganese to Sweden and Norway was strictly watched to prevent any leakage through to Germany, and supplies to Canada and to the United States have, during the whole period of the war, been kept up to the full demands made.

Italy, France and Spain have been supplied from this country, or from India. In the latter country the manufacture of ferro-manganese was commenced a year ago at the instigation of the Ministry, and has since been carried on with complete success.

PRODUCTION OF PIG-IRON DURING THE WAR PERIOD.

The production of pig-iron of all kinds in the United Kingdom since 1913 has been as follows :—

Year.	Hematite.	Basic.	Forge and Foundry.	Alloys.	Total Pig-Iron.
	Tons.	Tons.	Tons.	Tons.	Tons.
1913	3,604,823	2,529,800	3,801,547	324,145	10,260,315
1914	3,225,403	2,002,500	3,369,516	326,354	8,923,773
1915	3,564,276	2,272,684	2,701,215	255,484	8,793,659
1916	4,042,014	2,290,549	2,423,575	291,845	9,047,983
1917	3,921,927	2,722,791	2,378,870	298,190	9,321,778
1918	3,556,748	2,986,827	2,301,802	240,975	9,086,352

The figures for the years 1913 to 1916 (inclusive) are taken from the Iron and Steel and Allied Trades Federation Statistical Report for 1917 ; those for the years 1917 and 1918 are from returns made to the Ministry of Munitions. It will be seen that there has been a steady increase in the total output of pig-iron since the beginning of 1916 up to the beginning of 1918, against a decrease in the output of hematite pig-iron since March, 1917, owing to the necessity of restricting the importation of foreign ore in view of the shortage of shipping. The increase is due to an augmented production of basic pig-iron, since the output of foundry and forge makes has remained practically stationary.

SCRAP.

The fixing of prices for finished steel in 1916 at once affected the materials used in steel-making, and steps were taken on the 27th July of that year to bring steel scrap within the scope of the Control Order.

A meeting of the leading scrap merchants was called by the Department, and a preliminary discussion of the position of the supply and price of scrap took place. The result was the appointment of an Advisory Committee, composed of representatives of the principal firms. At first there was no shortage; but as time went on serious difficulties arose with regard to both supply and distribution. The movement of scrap prior to Government control had not been to any great extent direct from producer to consumer, but had passed through the intermediary of merchants, the business being largely speculative. The fixing of maximum prices interfered with operations of this nature, and was therefore regarded by a section of the merchant trade as a curtailment of legitimate business. Nevertheless, the great majority of responsible merchants accepted the position patriotically, and many of them showed every desire to help the Ministry over difficulties.

No statistics are available as to the total consumption of scrap by steel-makers prior to the war, or as to the amount of scrap used, but in general it probably did not exceed 30 per cent. of the charge, and in many cases was as low as 10 to 15 per cent. The shortage of pig-iron made it essential to utilise scrap to as great an extent as possible, and pressure was put upon steelmakers to increase the proportion up to 50 per cent. of the charge. To ensure this being done, each firm was requested to return the respective amounts of pig-iron and scrap used each month. After the first return the makers who were using only a small percentage of scrap were dealt with individually, and by this means after a few months a considerable saving in the consumption of pig-iron was effected. According to figures compiled by Mr. J. D. Stitt, who was in charge of the Section dealing with scrap-iron and steel, the average consumption of scrap was raised from 34 to 47 per cent. of the charge, thereby saving more than

750,000 tons of pig-iron per annum for the same ingot output. Under war conditions the normal sources of supply tended to disappear, but a new source became available as a consequence of the great programme of shell production which came into operation early in the war. This new supply consisted largely of steel turnings. So much of this material was available that steel-makers were quite unable to absorb it, and shell factories became blocked with accumulations. At first the only outlet was in the blast-furnaces, and although many owners protested their inability to use turnings, under pressure they ultimately agreed to do so. Its use was so effective in increasing the output of pig-iron at a low cost that, at a later date, when steel-makers were able to absorb a greater percentage, the diversion to steel-works was objected to by blast-furnace owners.

During the greater part of the years 1917 and 1918 there was an insufficient supply of steel scrap to meet the needs of the steel-makers. In coping with this shortage, valuable assistance was given by the Salvage and Central Stores Department of the Ministry and by the Consultative Committee of Merchants in bringing into the market materials that hitherto had lain dormant throughout the country. Arrangements were also made with the Admiralty and with the War Office for putting into circulation all possible scrap materials, either in the dockyards or under the control of the Home Commands, and for bringing salvage material home from the battlefields in France.

Swedish Pig and Bar-Iron.

Early in 1915 the steel trade in Sheffield represented to the Ministry that there was a danger of a shortage of Swedish pig-iron, bar-iron and steel, which would seriously affect the output of munitions. After discussion with the Sheffield steelmakers at a meeting held in April, 1915, it was decided that the Government should purchase certain quantities of these materials.

Accordingly arrangements were made in July for Mr. Albert Senior, of Messrs. George Senior & Sons, one of the

leading steel firms, to proceed to Sweden to purchase these materials on Government account, and he succeeded in obtaining 150,000 tons of them. In the first instance it was intended that as the shipments arrived the particular brands should be sold to the firms using them; but later on it was decided that it would be wiser to maintain a stock against any stoppage of supplies. It was realised that the market would certainly go against this country, and also that the exchange with Sweden would probably fall, both of which contingencies came about. It was also hoped that the various firms using Swedish iron would be gradually persuaded to adopt home material (see page 16).

The purchases made by Mr. Senior were all effected at advantageous prices, a large portion of the pig-iron being actually bought at very little above pre-war prices. Mr. Senior carried out his mission without any remuneration, either in the way of commission or salary, nor were the expenses of his journey charged to Government. The thanks of the Ministry in general, and of the Steel Department in particular, are due to him not only for these services, but also for his valuable advice in the disposal of the materials to the best advantage.

FIG. 6.—Extension to the Tees Furnace Co.'s Lackenby ironworks at Grangetown, showing new hot-blast stoves.

Facing p. 34.]

CHAPTER V.

CONTROL PRICES AND SUBSIDIES—IRON AND STEEL.

The control price fixed for hematite pig-iron (ordinary grades) was £6 2*s.* 6*d.* per ton on the East Coast and £6 7*s.* 6*d.* on the West Coast. For ordinary grades of pig-iron made by the basic process it was fixed at £4 17*s.* 6*d.* per ton. This did not apply to Cleveland basic for which the price was fixed at £5 per ton. For forge and foundry iron the control prices were between £4 7*s.* 6*d.* and £5 per ton. With regard to steel the process of manufacture was not considered in fixing the price: for ingots it was £8 10*s.* per ton, and for billets, £10 7*s.* 6*d.*

In September, 1917, an advance in miners' wages caused an increase of 2*s.* 6*d.* per ton in the price of coal. This threatened to disorganise the schedules of maximum prices for coke, pig-iron and steel ingots, as well as for finished iron and steel. Any advance in these prices would have been reflected in Government contracts for all descriptions of war material. In the majority of cases the adjustments would have been complicated, as it would have been practically impossible to prevent contractors and sub-contractors making an additional profit on the increased prices, especially where contracts were placed on the basis of cost, plus a percentage. Again, owing to the varying quantities of fuel used in producing different qualities of pig-iron, a uniform advance in prices would have unduly benefited certain makers. On the other hand irregular advances in pig-iron would have upset the scale of steel prices.

After a careful consideration of the whole situation it was decided that coke prices should be advanced, as from

September 17th, 1917, but that the maximum prices of pig-iron, steel and finished iron should remain unchanged, the consequent losses being made up to the makers of these materials by a subsidy. In those cases where steel-makers were making too great a profit the opportunity was taken to bring into operation a system of drawbacks. Treasury sanction was obtained for these arrangements, and the subsidies were adjusted in each district to represent as closely as possible the actual extra cost incurred. This system has remained in force up to the present date, the subsidies being increased, when necessary, to meet the extra cost arising from the advances in wages that have from time to time been sanctioned by Government.

The introduction of subsidies involved frequent negotiations with the various Employers' Associations, and a number of special arrangements had to be made with individual firms whose exceptional conditions did not allow them to sell profitably at the fixed maximum prices. To deal with these matters Mr. Walmsley, in addition to controlling pig-iron, was appointed Director of Iron and Steel Contracts, with Mr. Crookes-Harris as assistant. In August, 1918, in consequence of the work he had undertaken in the erection of gas-cleaning plants at blast-furnaces, in connection with the recovery of potash, Mr. Walmsley found it necessary to hand over the Directorship of Iron and Steel Contracts to Mr. J. Bruce Harding.

It is intended that the subsidies shall be abolished as early as possible after war-contracts are terminated; but, in order to avoid the dislocation of trade that might occur, if prices were suddenly allowed to rise to their true economic level, it has been decided to remove them in at least two stages. Those applicable to steel-making will be removed on 1st February, 1919, when a revised schedule of maximum prices for steel will take effect. Those applicable to pig-iron will continue until 30th April, when it is proposed that subsidies should cease entirely. The new price for steel ingots will be £9 5*s.* per ton, and for billets £11 12*s.* 6*d.* per ton.

Arrangements have been made, in consultation with the trades concerned, to secure an equitable distribution of pig-iron and steel so long as any subsidies continue. The powers possessed by the Government under the Defence of the Realm Act will, if necessary, be exercised to prevent any undue holding of subsidised material. It is not, however, intended that Government subsidies should be used to enable exports to be made to overseas markets at less than the full cost. The Ministry have therefore issued lists of export prices for both iron and steel which are calculated to include the full amount of the subsidies. The difference between the home and export prices will be levied as a drawback on all exported iron and steel.

CHAPTER VI.

EXTENSIONS TO BLAST-FURNACES AND STEEL-WORKS.

When it was realised that the war would assume huge proportions and that there was every prospect of its long continuance, new armament plant was constructed on a scale commensurate with the great demands of the army for projectiles and other war materials. The enormous consumption of shell-steel, and the fact that it took precedence over the requirements of the armament factories in respect of constructional steel and of steel used for other war purposes, produced a shortage of these materials, and steps were taken by the Steel Department to increase the output of ingots throughout the whole country.

As a result of this action extensions to steel-works, providing for two million tons extra output of ingots, were planned in the course of about three months, *i.e.*, by the end of March, 1916. This amount covered the immediate deficit; but since it was felt that any tonnage of steel that could be produced would be absorbed in the war and would tend to shorten it, the policy of sanctioning extensions was pursued right through the ensuing twelve months, the ultimate increase arranged for being about five million tons of ingot-steel. This policy necessitated corresponding increases in pig-iron, ferro-manganese, ferro-silicon, limestone, coke, firebricks, refractory materials, home and foreign ores, etc., all of which had to be arranged for by the Steel Department, Mr. P. G. Lewis dealing with coke-oven schemes, Mr. B. Walmsley with blast-furnaces and the supply of limestone, and Mr. John Hall with steel-works; while Captain R. J. Wallis-Jones was in charge of iron-ore and Mr. W. J. Jones of refractory materials.

While the Steel Department attended to all the materials necessary to produce the extra ingot output, the other Government Departments concerned were duly advised of the projected increases, in order that they might take the steps necessary to meet them at the time required, such departments being those dealing with Shipping, Labour and Transport.

After negotiation with iron and steel manufacturers for the construction of the new plant, agreements were made with a number of firms by which they undertook to do the work under the supervision and with the financial aid of the Ministry, the underlying principle of the financial arrangement being to leave the firms at the end of the war with modern plants at an approximately pre-war cost. All extensions that were sanctioned had not only to be designed to meet the direct necessities of the war, but were required to be convertible to general trade purposes after the war was over.

To enable these extensions to be planned on an economical and intelligent basis and so that they should be in balance with existing plant, particulars were obtained of the latter at those works where it was proposed to make an extension. An attempt was also made to make every district self-contained with regard to raw materials, the object aimed at being to put each works in a sound position to compete in the world's markets after the war. Further, by taking into account the pre-war imports of steel in making the arrangements it was hoped that on the completion of the extensions there would be no necessity to import a single ton of foreign steel.

One of Sir John Hunter's first acts as Director of Steel Production was to sanction the programme already formulated for increasing the output of the steel, and the coke and pig-iron, etc., essential to such increase. This programme represented 1,000,000 tons per annum of hematite steel, and 2,000,000 tons per annum of basic open-hearth steel, making with the original 2,000,000 tons a total increase of 5,000,000 tons per annum, or a total estimated future

production of 12,000,000 tons of ingot steel per annum. In September, 1916, a further programme was put forward by the Steel Department on tentative arrangements already made with various steel-works. This scheme, by which a further 1,250,000 tons per annum of ingot steel would have been obtained, was rejected by Dr. Addison, but during 1918 one or two of the items were reinstated.

In September, 1916, Mr. Fred Syme was appointed to deal with all the expenditure involved in these new plants. Previously it had been dealt with in Sir John Hunter's general Factory Department, but a separate Section was then formed for this purpose under Mr. Syme. Firms who agreed to extend their works were required in all cases to submit their proposals, with full particulars and drawings of the proposed installation, together with detailed estimates of the cost, output, etc., for the approval of the Iron and Steel Production Department. In this connection the Department received valuable assistance from Mr. D. E. Roberts, Consulting Engineer, of Cardiff.

After approval by the Iron and Steel Department each scheme was passed on to the Construction Department and thence to the Munitions Works Board for final sanction. The arrangement of financial terms and the drawing up of the contracts under which the work was to be carried out, were negotiated with the firms at first by Sir John Mann and subsequently by Mr. C. J. Maslin of the Contracts Department.

Delay occurred in the erection of nearly all these plants: this was due partly to the lack of labour caused by the Army requirements, and partly to the fact that, with so many extensions undertaken at one and the same time, the firms who dealt with this class of work were booked for months ahead, with consequent slow delivery of the necessary plant. From June, 1916, onwards continuous efforts were made to get skilled operatives returned from the Army, particularly for blast-furnaces, but with little success. Although in consequence of these drawbacks the progress of the extensions was seriously delayed, yet increased production began to

date from January, 1917, and has gone on steadily ever since. Had the difficulties, which were at first experienced in getting the extensions passed, not occurred, the delays due to labour would have been avoided, owing to the much more favourable conditions of supply that prevailed in the earlier period of the war.

The extensions to iron and steel works sanctioned by the Ministry in 1916, 1917, and 1918, consisted of 22 blast-furnaces and 166 steel-furnaces, the distribution of which is shown in the following tables :—

EXTENSIONS ARRANGED FOR IN 1916.

District.	New Blast Furnaces.	New Steel Furnaces.		
	Number.	Basic.	Acid.	Total.
Scotland	—	31	8	39
North-East Coast	2	14	1	15
Lincolnshire	2	6	—	6
Midlands	2	24	8	32
South Wales	3	7	5	12
Cumberland and Lancashire ...	4	10	8	18
Totals	13	92	30	122

EXTENSIONS ARRANGED FOR IN 1917 AND 1918.

District.	New Blast Furnaces.	New Steel Furnaces.		
	Number.	Basic.	Acid.	Total.
Scotland	—	—	—	—
North-East Coast	3	7	2	9
Lincolnshire	2	3	—	3
Midlands	3	14	2	16
South Wales	1	7	—	7
Cumberland and Lancashire ...	—	7	2	9
Totals	9	38	6	44

A considerable number of the steel-furnaces originally planned for the acid process were subsequently altered to work the basic process, owing to the falling-off in the supplies of foreign hematite iron-ore, and the increase in output of basic pig-iron brought about by the action of the Home Ore Supply Committee. New equipments for existing works and a number of rolling mills were also sanctioned.

The fact that these extensions were not completed at the dates originally arranged, prevented them being used for war purposes as fully as had been hoped. But the improvements introduced, both in plant and machinery, mark a great development in the steel-making industry of this country; and the new works will assuredly be a vital factor in the economic and industrial recuperation of the country. It is true that a few of the schemes will not be completed for a little time to come; but they are of considerable national importance, since they will be fed by home ores for the basic process of steel-making, and are specially designed to be self-contained, providing on the same site modern coke-ovens, equipped with by-product recovery plants, blast-furnaces, steel-works and rolling mills.

It should be noted, however, that the programme for extensions to steel-works, especially in regard to basic-lined furnaces, has out-stripped that for extensions to blast-furnaces; and since a number of the blast-furnaces that, as a temporary measure, have been producing basic pig during the war period, will most probably now revert to foundry or other grades, the basic steel-making capacity of the country will be left considerably in advance of its basic pig-iron capacity. During the last two years of the war the balance, as between steel-furnaces and blast-furnaces, was preserved by the importation of considerable quantities of pig-iron from America (see p. 23).

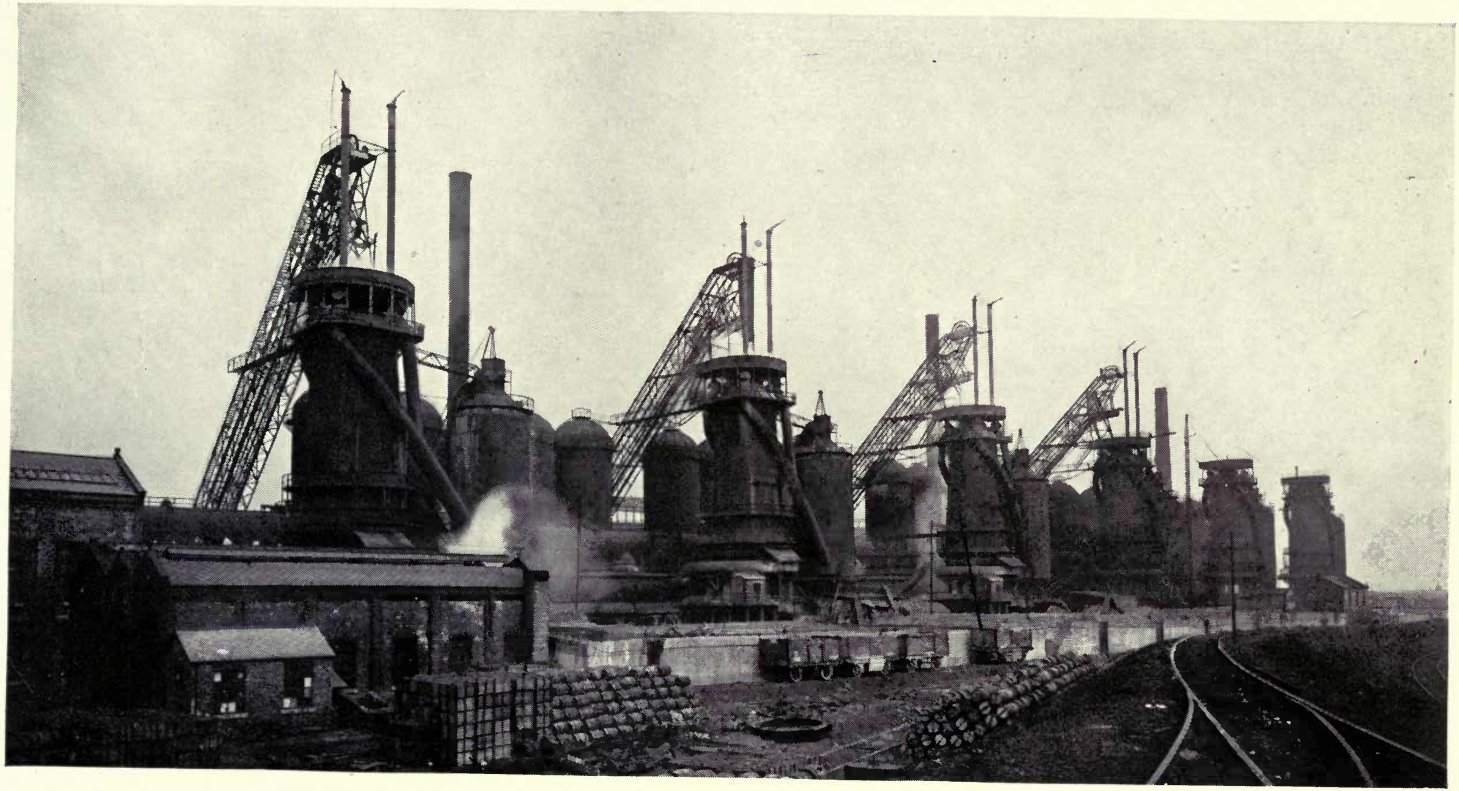

FIG. 7.—Blast-furnaces with hoists, and stoves at the Partington Steel and Iron Co.'s ironworks at Irlam, near Manchester. Two of the furnaces are new.

CHAPTER VII.

THE BASIC IRON PROGRAMME:

(*a*) Pig-Iron and Steel.

The problem of increasing the production of home iron-ore was a complex one: not only did it involve the provision of new labour, mechanical appliances, means of transport, etc., but, since the ores were in the main phosphoric, it meant an extensive rearrangement of plant and the replacement by basic material of the siliceous linings of many steel-furnaces hitherto used for the acid process. Moreover, since the home ores were of low iron-content (averaging 28 per cent. iron as against 50 per cent. for imported hematite), an increased number of blast-furnaces were required to produce the same output of pig-iron, and this, in turn, necessitated larger supplies of fuel and limestone. More furnaces in blast meant also an additional supply of the specialised labour required to man them; and the changing over of blast-furnaces and steel-furnaces to basic pig-iron and steel production involved the education of many managements in the technical details of a process to which they were unaccustomed. The large drafts of labour required for the increased production of the essential raw materials necessitated hutting accommodation, and in the case of prisoner labour, the prescribed equipment of prisoners of war camps as well as guards, technical supervision, etc.

Basic pig-iron had long been successfully produced at Scunthorpe and Frodingham with the North Lincolnshire limey ores. It had also been manufactured in the Midlands by the admixture of other favourable materials (such as Staffordshire "mine," tap-cinder, scale, etc.) with the

siliceous Northamptonshire ironstone. But the supply of these "other materials" was limited, and both the Northamptonshire and the Cleveland ironstone, on which dependence had to be mainly placed for a rapid increase of production of basic pig-iron, were *per se* unsuitable for the purpose. The problem was further complicated by the inexperience of many of the ironmasters in the manufacture of this class of iron and the unfitness of many of the furnace plants available.

It was realised at an early stage that the production, under these conditions, of any important increase of "Standard Quality" basic pig-iron (with maximum silicon 1 per cent. and maximum sulphur .05 per cent.) was practically impossible. It was therefore decided to discuss the situation with the leading steel-makers of the country in order to arrive at some agreement as to the widest margin in silicon and sulphur which could be allowed in pig-iron for the production in basic-lined open-hearth furnaces of a steel suitable for war purposes. A meeting was held at the Ministry of Munitions on the 2nd of March, 1917; and; after a lively discussion and the exercise of considerable persuasion on the part of the representatives of the Ministry, it was finally agreed, that, having regard to the national emergency, the steel-makers should accept for basic pig-iron a maximum silicon percentage of 1.5, a maximum sulphur percentage of 0.1 and a minimum manganese percentage of 1.25.

Immediately after this meeting a Section of the Department was formed to deal with basic pig-iron production and with the conversion of steel-furnaces from the acid to the basic process. It consisted of Mr. A. K. Reese, General Manager of Messrs. Guest, Keen & Nettlefold's Dowlais-Cardiff Works, Cardiff, and Mr. C. G. Atha, General Manager of the Frodingham Iron and Steel Company. Its duties were primarily (1) to bring about as great an increase as was possible in the output of basic pig-iron to offset the shortage in hematite pig-iron, (2) to increase the output of basic steel ingots to a maximum by a further increase in the basic pig-iron

output, and (3) to arrange for a sufficiency of basic-lined steel-furnaces by converting existing acid-lined steel-furnaces to supplement new basic furnaces under construction.

The Section first proceeded to ascertain what idle blast-furnaces were available, or could be made available for this purpose by installing, throughout the country, the necessary plant and equipment, without interfering with the production of other classes of pig-iron. From these were eliminated those furnaces whose situation was unfavourable for the transportation to them of the necessary materials for producing basic pig-iron. There were found available and suitably located for the purpose 36 furnaces, distributed as shown in the following table :—

FURNACES AVAILABLE FOR BASIC PIG-IRON PRODUCTION.

Districts.	No.	Furnaces.	Tonnage-Percentage of Total.
		Tons per week.	
Middlesbrough and S. Durham ...	8	6,400	35·5
Derbyshire	12	3,970	21·6
North Lincolnshire	1	700	3·8
Midlands—			
Staffordshire	2	1,200	6·5
Northamptonshire	5	2,300	12·5
Nottinghamshire	1	400	2·2
South Wales	3	1,800	9·7
Scotland	4	1,500	8·2
	36	18,270	100·0

There were also 16 furnaces under construction whose erection had been sanctioned by the Ministry previous to the formation of the Home Ore Supply Committee. It was anticipated that certain of these furnaces would be ready from time to time and would provide for a further increase of basic pig-iron, amounting in the aggregate to 14,000 tons per week.

This information having been obtained, negotiations were opened with the firms concerned, the position placed before them from the national standpoint, and their

co-operation requested on behalf of the Ministry. To those lacking experience in the manufacture of pig-iron by the basic process technical advice was offered. Many interviews and consultations were held, particularly with ironmasters operating in the Midlands, where in regard to both plant and material the difficulties to be overcome were greater than elsewhere. On the whole, the proposals of the Ministry met with patriotic support, even from those most sceptical of the success of the undertaking. Preparations were at once made to furnish the necessary materials and labour to those firms whose furnaces were fully equipped and in a condition to be put into immediate operation. Arrangements were also made with other firms for the installation of such additional equipment to their furnaces as was required.

During the first few months progress was slow : in various directions fresh obstacles were encountered, and to overcome these much persuasion, advice and assistance were necessary. Several blast-furnaces, when first put on to basic pig mixtures, failed ; this was partly through lack of experience and partly due to the materials being unsuitable for the production of the quality of iron desired. Such difficulties, however, were gradually overcome as experience was gained by the operators ; and in a few weeks a supply of pig suitable for steel-making was produced by these furnaces, the first output being in the week ending the 6th of May, 1917. But it was soon found that the operation of the additional furnaces was delayed by the difficulty of finding sufficient labour to man them. Steps were taken, therefore, to obtain the consent of the War Office for the return of blast-furnace operatives from the Army ; and finally arrangements were concluded for the release, on the application of the Labour Supply Department of the Ministry of Munitions, of men whose names were to be furnished by the Iron and Steel Department. Many of these men had to be brought from active service abroad (in France and in more distant theatres of war) ; consequently, they arrived in small numbers and at considerable intervals ; but as they

came forward they were allocated to those furnaces that were most nearly ready for operation. By these means, and with the assistance of men locally obtained and through the medium of the Labour Exchanges, additional blast-

Fig. 8.—Extension to the Partington Steel & Iron Co.'s ironworks at Irlam, near Manchester: New blast-furnace and stoves (Aug. 24, 1918).

furnaces were from time to time put into operation; and the efforts of the Committee were rewarded by a gradual augmentation of output.

By October, 1917, the increased production of basic pig-iron was already such that it became necessary to arrange for additional steel-melting capacity, and a campaign was

at once started for the conversion to the basic process of as many acid-lined steel-furnaces as possible. The necessary information was obtained from steel firms throughout the country and a programme was arranged for such conversions as structural suitability, location for pig-iron deliveries, and the class of steel made at the various steel-works permitted. This programme was immediately put into operation; but in cases where the acid process was being worked, the alterations could not be undertaken, having regard to the necessity of maintaining output, until the furnaces were due for general repairs. The re-lining of a steel furnace requires from six to eight weeks. Consequently, progress was at first rather slow; but in due course a considerable number of conversions were completed, and this in conjunction with the coming into operation of newly-constructed furnaces previously arranged for, caused an increase in the output of steel amounting to 33,300 tons per week by the end of April, 1918. In view of the serious shortage of hematite pig-iron for acid steel-making and the considerable increase in basic pig-iron production, these alterations came in most opportunely for the absorption of the basic iron produced under the programme. But for this circumstance the steel-ingot output would have seriously fallen off on account of the diminished iron-ore imports and consequent reduction in the output of hematite pig-iron.

At the date of the formation of the Home Ore Supply Committee the weekly output of basic pig-iron was 47,920 tons. It reached its maximum in the week ending the 5th of May, 1918, with 65,530 tons—an increase of 17,610 tons, of which about 10,000 tons is attributable to the coming into operation of extensions to blast-furnace plants and the balance to the employment of idle furnaces either requiring repair or previously used as "stand-bys." A certain proportion of the increase was also obtained by changing the "make" from hematite-pig or from forge and foundry iron. Similarly, the weekly output of basic steel was 71,500 tons at the date of the inception of the Committee and

reached its maximum in the week ending the 27th of April, 1918, with 104,800 tons—an increase of 33,300 tons per week.

It will be seen from these figures that the efforts of the Home Ore Supply Committee were rewarded by a very material augmentation of the increased production which was already in preparation under the original scheme of extensions to blast-furnaces and steel-works (see pp. 20 and 38).

In reviewing in September, 1917, the arrangements that had been made for the supply of pig-iron to the new basic steel-furnaces under erection it was considered that, owing to the number of acid-lined furnaces that had been converted to the basic process, a further provision of pig-iron producing capacity to the extent of 10,000 tons per week would be necessary in order to meet the requirements of the basic steel programme. Negotiations were, therefore, undertaken and arrangements completed for the construction of new blast-furnaces with the following firms: Lloyd's Ironstone Co., John Lysaght & Company, The Holwell Iron Company, and for the equipment of existing stacks with Dorman, Long & Company, Guest, Keen & Nettlefolds, Cardiff, Baldwins Limited, Landore, and The North Lincolnshire Iron Company.

By June, 1918, a number of blast-furnaces were ready for operation, but were unable to start owing to the shortage of the necessary labour both skilled and unskilled. At this stage difficulties arose with the War Office regarding the release of blast-furnace operatives from the Army, and it was only after a somewhat prolonged negotiation that arrangements were completed for the release of these men. Unfortunately, however, another hitch occurred. In order to supply the urgent needs of the Army for man-power in the early part of the year the Minister agreed in February to release from munitions works a large number of men, the proportion to be released from iron and steel-works being arranged by District Committees composed of representatives of both employers and workmen. This reduced the labour at many of these works to the absolute minimum required for the continuance of operations.

Immediately following the release of these "quotas" the War Cabinet ordered, in the latter part of June, a "clean-cut," under which young men born in the years 1898 to 1899, of Grade A 1 Medical Category, were called up without appeal. Blast-furnaces lost about 600 operatives. Many firms were unable to stand this further loss: at some works furnaces were blown-out, and the operatives utilized to keep the remaining furnaces going; while at others the furnaces were put on slack blast with consequent reduced output. The production of pig-iron and steel throughout the country naturally fell off very materially; but fortunately the situation was to some extent relieved by the opportune arrival of a number of blast-furnace men, whose release from the Army had previously been arranged for the purpose of manning additional furnaces. Of these men there were 123 in all. As they reported, they were distributed in such a way as to relieve the most urgent cases; but the supply was exhausted by the 15th August and only accounted for 20 per cent. of the number taken by the "clean-cut." Many furnaces remained undermanned and the reduced output continued. This curtailment of labour cut off all hope of raising the output of pig-iron and rendered nugatory any further effort to carry out the steel programme for the second half of 1918.

The serious falling-off in the output of iron and steel throughout the country soon became alarming, and on 22nd July, 1918, representations were made by the Iron and Steel Department to the Minister asking that steps should be taken through the Labour Supply Department for the return of the blast-furnace operatives called up under the "clean-cut." The sanction of the Minister having been obtained, meetings took place between the two departments and an arrangement was made for sending forward applications for 475 men, whose release and allocation to the iron-works most in need of them would, it was anticipated, increase the production of pig-iron by 5,000 tons per week. These releases were sanctioned by the War Cabinet on the 10th of September, 1918, and the men soon after returned.

CHAPTER VIII.

THE BASIC IRON PROGRAMME—*continued.*

(*b*) Labour and Machinery.

At its formation, Major R. A. Laws was asked to undertake the work of the Labour Supply Section, in addition to his duties as Secretary of the Committee. Primarily the Section was made responsible for providing the labour needed to carry out the programme for increasing the production of basic iron and steel; later on, its functions were extended.

The first step was to ascertain the labour requirements of the various branches of the industry (iron-ore mining and quarrying, limestone and dolomite quarrying, blast-furnace work, etc.), and firms were asked to make monthly returns of their demands. This information having been obtained, the Ministry of National Service, in conjunction with the Labour Supply Department, sent representatives to many parts of the country in search of any labour that might be available, or could be made available, by the withdrawal of men from less important work. As a result of this recruiting campaign men were transferred as War Munition Volunteers from the china clay industry in Cornwall and sent to work ironstone in North Lincolnshire and in the Midlands; and, similarly, Welsh slate-quarrymen were sent to work limestone in Yorkshire and Derbyshire. The Welshmen did not stay long: they were of inferior physique and could not earn the wages made by the local men on piece-work. The Cornishmen proved more successful: a number of them found employment in the Ebbw Vale Company's Irthlingborough mine, at the blast-furnaces of

Kettering and Holwell and on construction work at Frodingham; altogether some 500 Cornishmen are at present employed. In South Wales tinplate workers were recruited and sent to work on extensions to steel-works and blast-furnaces; they proved to be of inferior physique and unable to undertake successfully the heavy work required of them. Irish labour was also tried, but without success; and a suggestion to import Italian miners was dropped for political reasons. A certain number of men were obtained through the Labour Exchanges.

Considerable use has been made of prisoners of war (both civilian and combatant). For working ironstone in the Midlands, non-combatant prisoners of war were allocated to camps at Corby and Stainby and combatant prisoners to large camps at Rothwell near Kettering, at Pattishall south of Northampton, and at Uppingham and Wakerly near Stamford. Both combatant and non-combatant prisoners from these camps worked on a piece-rate system introduced by Mr. H. K. Scott, the Ministry's Representative at Kettering, in consultation with the camp commandants.

In view of the difficulties attaching to the employment of combatant prisoners of war the efficiency, as compared to British labour employed on similar work in the same neighbourhood, did not as a rule exceed 40 per cent. for baring, and 60 per cent. for loading ironstone (the actual figures ranged from 11 per cent. to 46 per cent. for baring and from 45 per cent. to 80 per cent. for loading). For interned aliens, who were more favourably disposed to effort, the efficiency ratio ranged from 65 per cent. to 80 per cent.

Combatant prisoners of war were employed in quarrying limestone; and camps were established for that purpose at Eastgate and Stanhope in Weardale and at Peakdale and Ladmanlow in Derbyshire. The Weardale prisoners worked with considerable success on piece-rates arranged by Mr. Hackney, the Ministry's Representative for that district. The output of a prisoner working in the Weardale quarries averaged about 17 tons per week as against 35 to 40 tons per week for British labour. In August, 1918,

the total number of German prisoners at work in these quarries was about 1,000. The number allocated to the Derbyshire camps was 500, and this was subsequently increased to over 1,000.

Combatant prisoners were used in ganister quarries; and camps for that purpose were established at Harperley near Wolsingham and Healyfield in County Durham, the total number so employed being about 340. Prisoners of war to the number of 300 also worked in the iron-ore mines of the Isle of Raasay, off the West Coast of Scotland.

The efficiency of prisoner labour was much diminished by the restrictions of the War Office in regard both to rations and payment. Where it was possible to relax in some degree the regulations, as in the case of interned civilian labour, much better results were obtained.

To furnish the proportion of ore, which it had been estimated the Cleveland mines would contribute to the total called for by the basic iron programme, additional labour, amounting to 2,700 men, was required. At the same time it was not anticipated that it would be possible to obtain the release of local men who had joined the Colours; and in any case no risks could be taken. Since no housing accommodation was available for imported labour it was decided to erect hutments, and these were located in seven different camps in order to secure an adequate distribution of the men in relation to the mines.

As it turned out, the Department was able to obtain the release from the Army of over 1,000 miners belonging to the district; and, since these men were accustomed to the work, they were probably equivalent to double the number brought in from outside. On the other hand, the whole of the large increase in production, for which provision had been made, was not required, since the basic iron programme, for reasons that have already been given (see p. 50), was not completely carried out. Thus it happened that the camps were not put to the use for which they were originally intended; and ultimately they were converted to military

purposes, a part being made over to the Air Board and the remainder loaned to the Army.

Valuable assistance was rendered to the Department by Mr. Harry Dack, the Agent and President of the Cleveland Miners' and Quarrymen's Association, who worked patriotically in the national interest. During four years of exceptional strain he and the Resident Engineer, working in harmony, so tactfully handled the difficulties that arose in various directions (*e.g.*, the application of the War wage, the use of German prisoners in the Weardale limestone quarries, the calling-up for the Army of the men born in 1898–99, etc.), that work was carried on in the Cleveland district without any mine or quarry standing idle for a single day ; in many instances even the recognised annual holidays were foregone, the owners making an extra allowance in wages to the miners for the holidays so worked.

Camps were also established in Cumberland ; and 800 miners from the Scottish coalfield were brought into the district to assist the local miners in increasing the production of hematite. Reference to the special labour problems of this district is made in another Chapter (see p. 81).

When the scope of the Section was enlarged to embrace the supply of labour for extensions to steel-works and other buildings erected under the Direction of the Factory Construction Department, the protection of men of military age employed by the contractors employed on essential work became a matter of importance ; and schedules were drawn up by the Labour Supply Department and the Ministry of National Service, in agreement with the War Office, to show the trades and ages of the men it was decided should be protected. All applications to the Ministry of National Service for certificates of protection were first submitted to the Section for verification.

Previous to May, 1917, all men employed by controlled firms engaged on munition work were badged and entitled to protection from military service. At the end of April, 1917, these badges were withdrawn, and the Munition Area Recruiting Scheme was introduced. Under this scheme

workmen engaged upon munition works became entitled to protection from military service when they attained the various ages specified in the Schedule of Protected Occupations (M.M. 130). In the case of highly-skilled or pivotal men below the ages specified, exceptions were made and special applications put forward for temporary protection. The applications were in the first place made to the Labour Supply Department, but the Section was consulted as to the technical skill of the men and the necessity for retaining them.

Mr. A. C. Williams who had joined the Labour Supply Section in May, 1917, took it over from Major Laws in September, 1917. At the same time it was arranged that Mr. A. K. Reese should deal in his Section with the supply of skilled labour for blast-furnaces (see page 49).

The work of the Section in connection with labour supply and protection continually grew with the increased production brought about by the basic iron programme. The protection of " pivotal " men below the ages, for which normally protection was allowed, became the subject of much investigation. Questions of priority bearing on the iron and steel trade, or trades ancillary thereto, that came before the Labour Supply Department were referred to the Section before being put forward for grading to the War Priorities Committee.

In November, 1917, all firms engaged in building or constructional work were withdrawn from the list of firms coming under the Munitions Area Recruiting Scheme, and it then became necessary for these firms to apply (under A.C.I. 765 of 1916) for the protection of such of their workmen as were of military age. The names were first submitted to the Section for consideration, and its recommendations passed through the Labour Supply Department to the Ministry of National Service. Only men absolutely essential for the efficient carrying out of the work in question received certificates of temporary exemption.

In consequence of a further call for men by the Army, the Schedule of Protected Occupations was revised in February, 1918, and the age limit in many of the occupations

raised. As a result of this revision a large number of men were lost to the industry and demands for additional labour became very heavy. The firms concerned worked loyally in the matter of the dilution and upgrading of their workmen which was thus necessitated, and in a short time the disorganisation resulting from the withdrawal of men was considerably diminished.

Special measures had to be taken to deal with the men engaged in the manufacture of drop-forgings, stampings and castings, and technical advisers were appointed by the Controller of Forgings and Castings to confer with the Dilution Officers on questions arising out of the retention of highly-skilled men in these branches.

In March, 1918, the Forgings, Stampings and Castings Department became affiliated to the Iron and Steel Production Department and labour questions connected therewith were then referred to the Section. The shortage of men engaged in these industries was acute; and, since the Department had been called upon for a large increase of output in connection with the aircraft and tank programmes, special steps had to be taken to prevent any further recruitment of men so engaged and to obtain the release from the Army of those who had previously been in these occupations.

Owing to the seriousness of the military situation on the Western Front at the end of March, it became necessary to call to the Colours all available men, and instructions were given for released men to report for service immediately. In so far as the men engaged in metal-mining and quarrying, in the silica and firebrick industries, in tube manufacture, or on machine-guns and tanks, were concerned, these instructions were cancelled almost immediately; but much temporary disorganisation was caused and many men were taken who were afterwards returned when the situation became easier.

At the end of April, the War Cabinet decided that men born in the years 1895–99 and of medical category Grade 1, were to be called up for military service.

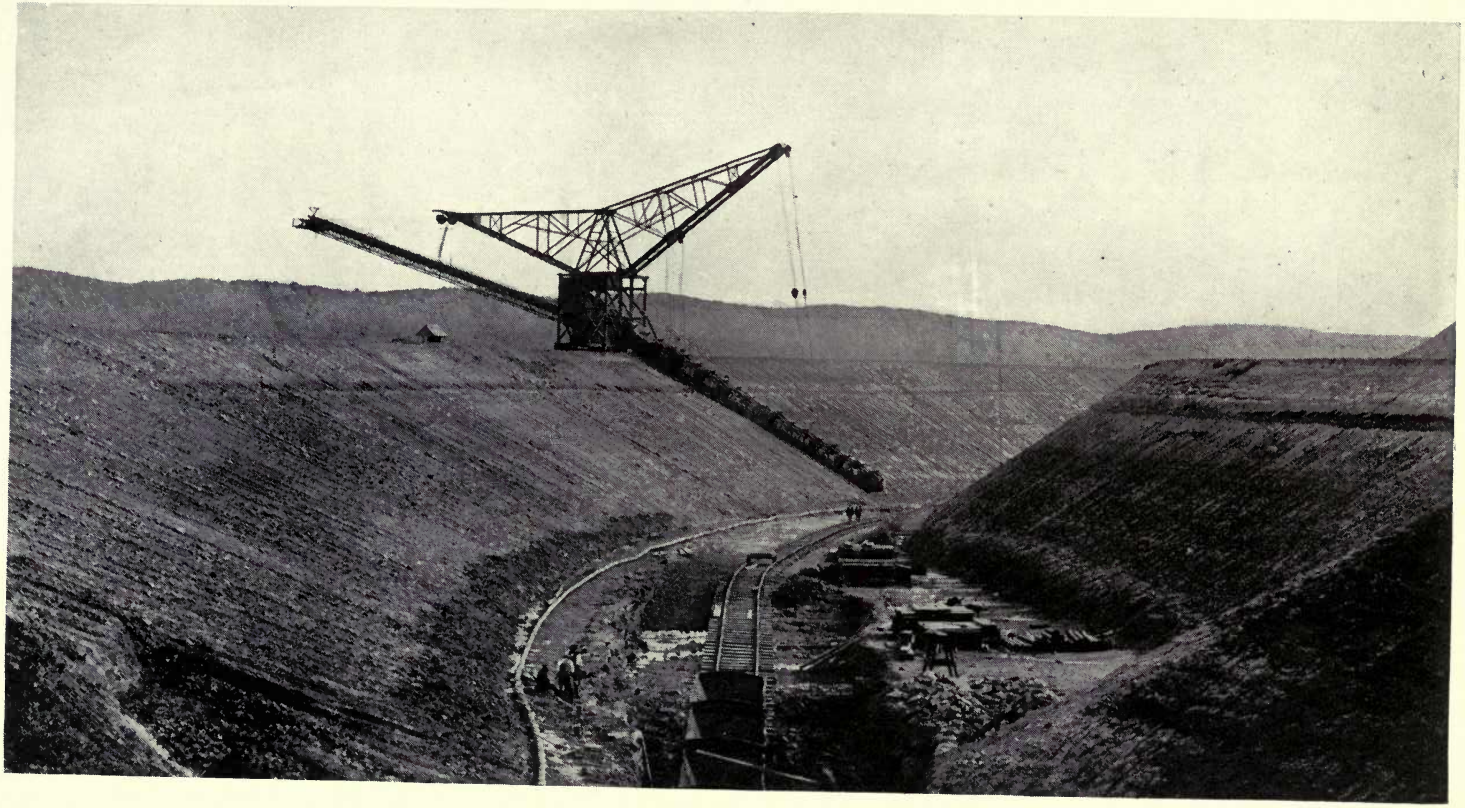

FIG. 9.—Bucket-excavator and transporter for removing cover at the Frodingham Iron and Steel Co.'s quarries in North Lincolnshire. The cover, consisting of sand and clay, is 50 feet thick; the ironstone, 24 feet thick.

At first, however, firms were permitted to apply for the retention of their highly-skilled men; but on the military situation becoming worse it was decided that no application for men born in the years 1898–99 should be considered, and all such men were ordered to join the Colours almost immediately. It was felt that the effect of this "clean-cut" would be disastrous to the iron, steel and kindred trades, and strong efforts were made to obtain a revision of the Order. Eventually, in June, it was decided to give the Ministry discretionary powers as to skilled men born in the years 1895–6–7.

On the 1st of November, 1918, Army Council Instruction 765 of 1916 was cancelled and an addition to the Schedule of Protected Occupations known as M.M. 130 B.W. was instituted. Protection was afforded thereby to men engaged on Government constructional work who were entitled to such protection under the terms of the Schedule, and exemption certificates were issued to them direct. A considerable amount of clerical labour was saved by this procedure, and many difficulties, which had arisen in connection with the carrying out of Army Council Instruction 765 of 1916, disappeared.

In July, 1917, a Section was formed by Mr. Ernest Craig, M.P., to deal with the labour disputes, wages and questions arising out of the "dilution" and "upgrading" of labour, in so far as these matters affected the industries controlled by the Iron and Steel Production Department. To assist him, Mr. Craig enlisted the services of Mr. W. J. Dunnachie and Mr. James Gavin, who were lent to the Iron and Steel Department by the Wages Section of the Labour Supply Department. Practically speaking, Mr. Craig's Section acted as a link between the Iron and Steel Department, the Committee of Production, the Labour Department of the Ministry of Munitions, the Ministry of Labour and the Ministry of National Service. Its work was directed mainly to the solution of labour problems, the interpretation and harmonizing of awards, the settling of disputes, etc.

These duties involved much investigation on the spot both by Mr. Dunnachie and Mr. Gavin, and as a result marked

success in the prevention and determination of strikes was achieved. Mr. Craig's wide and varied practical experience of labour and labour conditions was invaluable in enabling satisfactory settlements to be obtained.

In the East Midlands District a state of industrial unrest was created early in 1917 by the absence of machinery for the settlement of grievances of the men employed on blast-furnaces and in ironstone quarries. At the suggestion of the Controller of Iron and Steel Production, Mr. H. K. Scott convened a conference in August, 1917, between the employers and the representatives of the two principal trades unions concerned. The excellent results obtained led ultimately to the decision that similar conferences should be held quarterly. In January, 1919, Committees of Employers and Men's Delegates were appointed to discuss the details of a working agreement with a sliding scale as a basis. It is hoped that the principle of mutual agreement is now firmly established in this industry.

In view of the shortage of labour, the use of mechanical excavators and transporters for stripping and working the ironstone in the quarries has been of the first importance. Mr. T. M. McAlpine was asked by Sir John Hunter on the formation of the Home Ore Supply Committee to organize the supply of these machines. He first secured from the manufacturers a list of the plant made by them over a period of years and by this means was able to trace the whereabouts of all second-hand machines and ultimately to secure the greater proportion of them. Since the formation of the Home Ore Supply Committee the Ministry has been instrumental in placing 51 steam-diggers and 13 transporters, and such locomotives, rails, sleepers, air-compressors and other machinery as were required to complete the equipment of the excavating plant.

The advantage of mechanical loading over hand-labour is very great; apart from the fact that it enabled ironstone to be worked, which, on account of the labour shortage, could not have been touched, it served to steady the output, inasmuch as machine work is not affected

by weather conditions or sickness to the same degree as hand-labour.

The actual saving of labour which resulted from the installation of the above-mentioned mechanical plant is estimated to have been over 3,000 men. This will be found to be an under-estimate, if it be borne in mind that while ironstone quarrymen are skilled, the additional labour procured during the War for ironstone quarrying was entirely unskilled.

CHAPTER IX.

THE BASIC IRON PROGRAMME—*continued.*

(*c*) TRANSPORT.

At the time when the Home Ore Supply Committee was formed some of the quarry-owners in the Midlands stated that they could increase their output of ironstone by 15 to 20 per cent. without additional labour, provided that the railway companies could furnish the necessary facilities. This matter was gone into by Mr. T. M. McAlpine with the result that within a few weeks the promised increase was obtained.

Mr. Palmer was asked in April, 1917, to organise a Section of the Iron and Steel Department specifically charged with the transport of the increased output of ironstone and limestone, which it was estimated would result from the carrying out of the basic iron programme. On investigation he found that the ironstone was in the main sold f.o.t. at the quarry with the result that the efficiency of the wagons employed on this service (that is to say the quantity conveyed per wagon in a specified time) was poor, especially in the case of privately-owned wagons.

The problem was further complicated by the fact that the variable methods in use for loading wagons necessitate the employment of several different types of truck. Where the loading is by hand a low wagon is required, or one with centrally placed side-doors, opening to the top, so as to permit the ore to be thrown in conveniently. With steam-diggers, on the other hand, the wagon must be large and consequently high. In some quarries the material is hauled in small trucks to tips, or tipples, for transfer to

the railway wagons; in such cases the position of the tips limits the height and the width of the wagons employed. Similarly, the sharp curves on some of the tracks serving the quarries limit the length of the wheel-base.

The conditions at the ironworks vary even to a greater extent than those at the quarries. In some works the ironstone is required to be discharged directly into calciners. In others, the wagons have to be raised up to gantries and the ore there transferred by bottom-discharge into bins. In such cases, the wagons are pushed up by locomotives, pulled up by winding engines of limited capacity, or raised by elevators. Some works are not even provided with gantries, but require delivery on to plates at rail-level, from which re-loading into trollies, or skips, for elevation to the furnace-top is necessary. Frequently, in consequence of the absence of any stocking room, the stone has to be held in wagons until the furnace is ready to receive it.

Upon ascertaining these facts, Mr. Palmer first divided the Midland ironstone-field into districts and appointed a Transport Inspector for each—with the initial duty of keeping running sheets of the privately-owned wagons and generally of increasing efficiency by any means within his power. The districts were as follows:—

North Lincolnshire—with headquarters at Scunthorpe.			
Leicestershire	,,	,,	Melton Mowbray.
Northamptonshire and Rutlandshire	,,	,,	Kettering.
Oxfordshire	,,	,,	Banbury.

An Inspector was also appointed to the Cumberland District and stationed at Whitehaven.

Owing to the enormous drafts made on rolling stocks for transfer to the western front, no relief to the shortage in wagons could be obtained from the railway companies; and steps were therefore taken to arrange for a supply of the types most suitable for immediate requirements. Under the Defence of the Realm Act, 2,000 wagons were commandeered from various collieries. Upon collection and inspection, it was found that many of these were entirely

unsuitable for iron-ore traffic; but a sufficient number were purchased to enable the Inspectors to keep the furnaces supplied. Of the 2,000 inspected, 1,484 were eventually accepted. Since it was seen that, even with these, the supply would eventually be entirely inadequate, it was decided to build a further 1,800. A design was obtained for a 12-ton wagon having low sides, and the Railway Materials Branch of the Ministry undertook the construction and placed contracts with wagon-builders. In accordance with the various requirements some were provided with full-length side-doors, some with central side-doors and some with both central and bottom doors. Deliveries began in September, 1917, and were completed by April, 1918.

Late in 1917 it was foreseen that within a short time large quantities of ironstone from the Midlands would be required in South Wales and in the Cleveland District and that the labour available for discharging wagons would be limited. The ironworks in these districts are in nearly all cases equipped to receive the stone in hopper-bottom wagons; and no suitable wagons being obtainable for this service the Railway Materials Branch was instructed to proceed with the construction of 1,950 (subsequently reduced to 1,525), wooden hopper-wagons of two types, namely: a large type having a capacity of 20 tons of Northamptonshire ironstone; and a smaller type having a capacity of 15 tons or 20 tons of foreign ore. The delivery of these wagons began in small quantities in July, 1918; but owing to the congestion at the builders' works, the order was not completed at the time of writing.

The quarry being the natural home of the wagon, it was considered less complicated to allocate the wagons to the producers, notwithstanding the fact that the latter were in no way liable for deliveries once the materials were placed f.o.t.

After much discussion as to whether the wagons were to be controlled and operated by the Iron and Steel Production Department of the Ministry, or were to be made over to the various railway companies as common user wagons, the former

procedure was adopted. It was decided, excepting in a few instances, to hand the wagons over to the producers on a mile-tonnage base, the Ministry to receive monthly the actual amount earned by the wagons. The customary rates, however, were ascertained from point to point and these were the rates paid by the producers, who in turn collected from the receivers. No charge was made to the railway companies when the wagons were employed as common users.

A great many of the colliery wagons taken over were found to be in a bad state of repair. A small organisation was therefore formed to attend to the repairs. Its work was briefly as follows: advices were received daily from the various railway companies stating what wagons had been stopped for repair, where they had been stopped, and the nature of the repairs necessary. So soon as these were received they were checked over to see if the wagons quoted belonged to the Ministry. If so, they were entered in the repair ledger and listed out the same day to the wagon-repairing firm which had an out-station nearest to the stopping point. For small repairs schedule prices were obtained from the Association of Wagon Repairers and from firms outside the Association. When heavy repairs were required, the wagons were sent into the nearest shop that could take them. Before being stripped, they were examined by the Repair Inspector, who specified the work to be done. The specification was sent to the Head Office together with the repairing firm's detailed price, and, if the latter was satisfactory, it was sanctioned. Upon completion the wagon was again inspected before being allowed to go into traffic.

In the Cleveland district, where much trouble had been experienced at the furnaces, owing to the difficulty of regulating the deliveries of limestone and ironstone, it was decided in the summer of 1916 to form a local committee to control the whole of the mineral traffic (excluding foreign ore) received at 75 blast-furnaces and 10 large steel-works

of the district. This committee was formed on the 10th of October, 1916, and was constituted as follows :—

THE MINERAL TRAFFIC CONTROL COMMITTEE (CLEVELAND AREA).

J. J. Burton J. E. James Illtyd Hedley J. T. Naisby	representing the Cleveland Ironmasters.
T. H. Royle H. M. Sinclair	representing the North Eastern Railway Co.
W. E. Adamson J. Blumer F. Hall	representing the Limestone Quarry Owners.
G. E. Stephenson (succeeded in November, 1917, by H. B. White) N. G. Hackney	representing the Ministry of Munitions.

Mr. Burton was elected Chairman and Mr. T. Grice, of the North Eastern Railway Company, appointed Secretary. It was the duty of the Secretary to regulate and distribute the raw materials to the consumers in such a manner as to keep the works fully supplied while reducing the congestion of wagons and the overstocking of materials. By these means not only were regular supplies furnished to the blast-furnaces and steel-works under control in the district, but the strain on the supply of mineral wagons was relieved by reducing the time that the wagons had to stand under load at the discharging points. The following is a summary of the traffic received at the blast-furnaces in the district during the year 1917 :—

	Tons per annum.
Coal	2,885,250
Coke	2,777,280
Ironstone from the Cleveland mines ...	4,907,016
Limestone	1,699,080
Lime and Basic Material	182,000
Total	12,450,626

In addition, a quantity of ironstone amounting to some 12,000 tons per week in June, 1918, was supplied to Middlesbrough furnaces from the Northamptonshire district.

Under the Committee's supervision not only were the works kept fully supplied with limestone, but by November, 1917, 140,000 tons had been placed to reserve stocks at the works, to be drawn upon during the winter when bad weather interferes with quarrying.

CHAPTER X.

THE BASIC IRON PROGRAMME—*continued.*

(*d*) The Supply of Home Ore.

In the beginning of March, 1917, a Section was formed to deal with the mining and quarrying of iron and manganese ores, and of limestone. At headquarters it at first consisted of Mr. Frank Merricks, who up to that time had acted as Honorary Mining Engineer to the Ministry, and Dr. F. H. Hatch, Past-President of the Institution of Mining and Metallurgy, with Mr. Merricks as responsible head. Later on, as the work at headquarters grew, Mr. S. J. Lett was appointed Technical Secretary to the Section and Lieut. R. Butler, Technical Assistant, with special reference to the supply of limestone. In order to keep in close and sympathetic touch with the producing firms, Mr. Merricks divided up the country into districts, each of which was placed in charge of a responsible Resident Mining Engineer. These Resident Engineers took up their duties at the beginning of March, 1917, the different districts to which they were appointed and the stations assigned to them being as follows :—

District.	Station.	Resident Engineer.
Cumberland and Lancashire ...	Whitehaven ...	Mr. W. Selkirk.
Cleveland	Saltburn ...	Mr. G. E. Stephenson.
Midlands	Kettering ...	Mr. H. K. Scott.
North Lincolnshire	Scunthorpe ...	Mr. E. Edwards.
Oxfordshire	Banbury ...	Mr. A. A. Dolan.

Mr. N. G. Hackney had already been appointed (in August, 1916) to take charge of certain limestone and ganister quarries in County Durham, which were being worked by prisoners of war, and was stationed at Wolsingham.

Mr. Stephenson resigned his post at Cleveland to take up other duties on the 30th of November, 1917, and was replaced by Mr. H. B. White. Mr. Selkirk, who became Deputy Controller of the Cumberland and Lancashire iron-ore mines on the 24th of September, 1917, resigned in January, 1918, and Mr. W. T. Anderson, who succeeded him, was appointed Controller, with Mr. C. D. Wilkinson and Mr. M. MacLachlan as Deputy-Controllers. Mr. H. K. Scott was appointed Director of Home Ore Supplies for the Midlands on the 9th of March, 1918.

The preliminary organization having been completed, the next step was to obtain accurate statistics of the production of home iron-ore; and with this end in view producing firms were asked to furnish weekly returns to the Resident Engineers stationed in their respective districts. Over ninety per cent. of the production was from districts to which Resident Mining Engineers had been appointed, as will be seen in the following table, which gives the tonnage ratio of the output of the different districts to the total production for the year 1918 :—

Districts where Resident Engineers were Stationed.	Tonnage Ratio of Output to Total Production. Per cent.	Per cent.
Cumberland and Lancashire (hematite ore)	10·3	
Northamptonshire and Rutlandshire (Inferior Oolite ironstone)	23·1	
Cleveland district (Middle Lias ironstone)	30·2	
S. Lincolnshire, Leicester and Oxfordshire (Middle Lias ironstone)	10·0	
N. Lincolnshire (Lower Lias ironstone)	17·5	
		91·1
Other Districts.		
English and Scottish Coalfields (blackband and clay-ironstone)	7·5	
Raasay (Lias ironstone)...	0·6	
Wales (hematite and brown iron-ores)	0·5	
Forest of Dean (hematite and brown iron-ores) ...	0·1	
Weardale (spathic ore)	0·1	
Antrim, Ireland (Tertiary ores)	0·1	
		8·9
Total	...	100·0

In these latter districts local conditions did not warrant the stationing of a Resident Engineer; consequently it was arranged that the returns of output should be made direct to headquarters. But in the case of Scottish coalfields, where there are a great number of small producers, it was found more convenient to obtain the returns through the instrumentality of the Scottish Advisory Committee on Iron and Steel Production, of which Mr. Fred Lobnitz was Chairman, and Messrs. Wallace Thorneycroft, A. K. M'Cosh and G. A. Mitchell, members.

IRON ORE PRODUCTION OF THE U.K. IN DISTRICTS.

Districts.	1917.		1918.	
	Tons.	Tons.	Tons.	Tons.
WEST COAST—				
Cumberland	1,256,393		1,229,231	
Lancashire	330,036		320,731	
		1,586,429		1,549,962
CLEVELAND		4,809,861		4,570,892
NORTH LINCOLNSHIRE ...		2,699,532		2,639,712
MIDLANDS—				
Kettering	2,275,314		2,390,847	
Melton Mowbray ...	780,025		757,161	
Market Overton ...	585,121		739,407	
Uppingham	168,760		200,145	
S. Lincolnshire	216,408		199,625	
Blisworth	81,189		95,243	
		4,106,817		4,373,428
OXFORDSHIRE		434,435		580,659
RAASAY		65,985		88,047
COALFIELDS—				
N. Staffordshire ...	761,230		694,803	
S. Staffordshire ...	17,766		29,192	
Scottish	371,424		357,373	
Sundry	44,462		37,847	
		1,194,882		1,119,215
WALES AND FOREST OF DEAN—				
Wales	69,291		71,921	
Forest of Dean	21,477		13,498	
		90,768		85,419
MISCELLANEOUS—				
Ireland (Tertiary ore) ...	20,649		17,215	
County Durham and Devonshire	18,544		19,824	
		39,193		37,039
Total		15,027,902		15,044,373

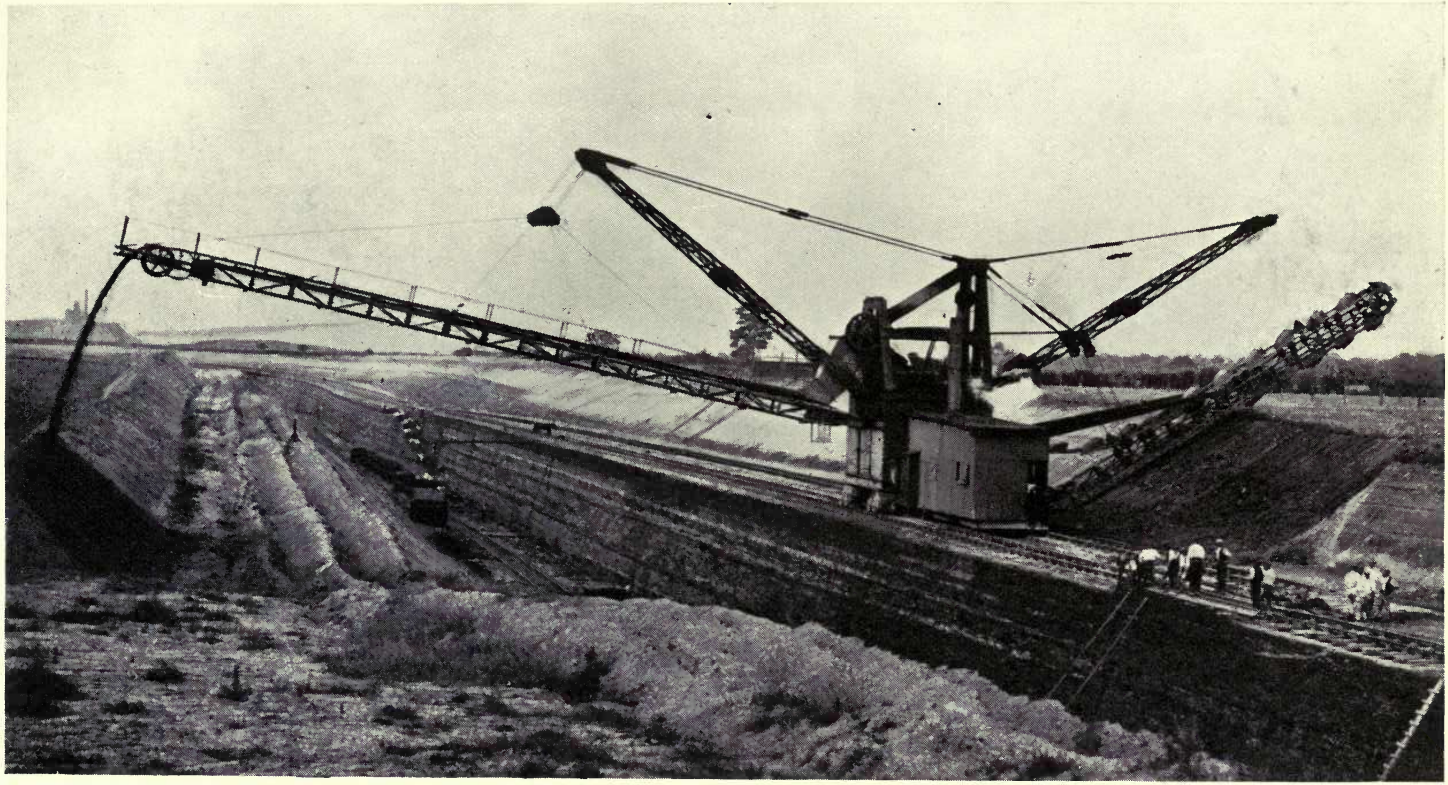

FIG. 10.—Bucket-excavator and rubber-belt transporter at the Frodingham Ironstone Mines, North Lincolnshire.

The collection and collation of returns of output was so organized that it was possible to furnish the Minister with a weekly report giving full particulars for the preceding week of the iron-ore and ironstone production of the United Kingdom.

For administrative purposes the returns were grouped under the heads shown in the preceding Table, which also gives the output for each district for the years 1917 and 1918.

The above figures represent the output of raw ironstone as mined or quarried. In the case of the blackband and clay-ironstone mined in the coalfields the output is usually calcined at the mine, a considerable reduction in weight being thereby effected. This is probably the explanation of the slight difference in the totals of the returns of the Ministry of Munitions and those of the Home Office.

With the exception of the hematite ore mined in Cumberland and Lancashire, the whole of this production is phosphoric and is used for making basic, foundry and forge pig-iron.

In consequence of a speech made by Mr. Lloyd George in the House of Commons in February, 1917, in which he referred to the importance of saving shipping tonnage by cutting down the import of hematite from Spain and developing home resources of iron-ore, the Ministry received many reports of extensive unworked deposits of iron-ore which the writers claimed could be utilized to form immediate and valuable additions to the home production. This led to much investigation on the part of the Mining Section. Attention was especially directed to Cornwall, Devonshire and Somerset, it having been reported to the Department that in these counties large quantities of ore were immediately available. Dr. Hatch, after a close examination of the iron-ore lodes traversing the Devonian rocks of these areas, on which in some cases much work had been done in the past (*e.g.* at the Restormel mine near Lostwithiel, on the Great Perran lode near Newquay, on the carbonate veins of the Brendon Hills, etc.), reported that, whatever the ultimate prospects of the occurrences in question might be, there was no chance of any of them

being brought to the producing stage within the period of the war. Lieut. Butler, who subsequently examined the hematite lodes of Lanjew, Coldvereath, Colbiggen and Prideaux, situated in the killas rocks surrounding the Hensbarrow granite between St. Austell and Bodmin, and the Brixham and Sharkham hematite deposits in Devonian limestone near Torquay, came to a similar conclusion.

With regard to South Wales Mr. Stephen Vivian kindly volunteered to give the Department the benefit of his special knowledge. After a careful re-examination in the Spring of 1917 he reported that the hematite deposits occur at intervals between Pentyrch, six miles north-west of Cardiff on the east and Bridgend on the west. They were exploited fairly extensively from 1840 to 1890 (in the Old Garth, Mwyndy, Bute, Trecastle and Llanharry mines) and yielded in the aggregate some 3,000,000 tons of ore. But, with the exception of the Llanharry mine, which is being worked by the Cardiff Hematite Iron Ore Co., and has produced about 60,000 tons per annum during the last three years, all work has long been stopped; and the abandoned mines are to-day waterlogged, so that a considerable amount of exploration would be necessary before the value of any remaining deposits could be determined.

An examination was also made of the Forest of Dean and South Wales occurrences of hematite and brown iron-ore in Carboniferous limestone and of the pisolitic and colitic iron-ores interbedded with Ordovician slates in Carnarvonshire.

In the Forest of Dean it was found that the irregularity of the deposits, the amount of dead work required to locate and prospect the pockets or " churns," and their comparative insignificance when found, gave small hope of any increase in production being obtained from this source. The total output of the district for 1917 averaged 400 tons a week and it fell considerably during 1918. having averaged only 260 tons per week during that year.

The pisolitic iron-ores of Carnarvonshire were examined by Lieut. Butler. They occur in beds of considerable thick-

ness over a wide stretch of country (Llàndegai near Bangor, Aber near Llanfairfechan and Bettws Garmon in Carnarvonshire) and consist of brown iron-ore near the surface, passing into carbonate in depth. On account of their sulphur and silica contents they can only be used as mixing ores and in limited proportions.

An investigation into the blackband and clay-ironstone of the English coalfields by Mr. H. K. Scott showed that here also no large increases of output were to be expected, the larger and more profitable seams having for the most part been worked out. The iron-ore is derived in small quantities from a number of pits and in many cases is only a by-product of coal-mining. As has already been shown on p. 67, the output from these sources does not amount to more than eight per cent. of the total production. The ores raised in the coalfields south of the Tweed come principally from North Staffordshire. They consist in this district of small seams of blackband-ironstone ("Half-yard," "Red Shagg," "Red mine," and "Bassey mine" seams) which occur in association with sufficient combustible material to permit of calcination in the open without the addition of further fuel, and of clay-ironstone ("Burnwood," "Cannel Row" and "Pennyside" seams) which require the addition of fuel for calcination. The calcined "mine" is classified either as "puddle-mine" or "steel-mine"—a high-grade material (with over 60 per cent. iron) which is used for the bottoming and fettling of puddle-furnaces and for oxidising purposes in steel furnaces, or as "furnace-mine"—a slightly inferior quality (55 per cent. iron) which goes to blast-furnaces. The maximum price of steel and puddle-mine was fixed at 40*s.* per ton, and that of furnace-mine at 30*s.* per ton. In order to meet the advances in miners' wages and in the price of coal it was agreed as from 1st July, 1918, to pay, in the case of certain mines of the district, an additional subsidy varying from 2*s.* to 7*s.* per ton on the tonnage of the raw stone raised.

In the South Staffordshire coalfield the ironstone occurs sporadically in "balls" or as thin seams in connection with

the coal. The principal supplies are obtained from the "White" ironstone above the "Heathen" coal and from the "Gubbin" ironstone below it. Small quantities are also obtained in working the "Brooch" and "Thick" coals.

In Wales a small quantity of ball-ironstone is obtained in working coal, both in South Wales and in Flintshire and Denbighshire.

An examination of the sources of supply in Scotland by Dr. Hatch in the early part of 1917 showed that the output of ironstone in the Central coalfield did not amount to more than some 6,000–7,000 tons a week, and was incapable of any considerable expansion, as the ironstone was derived from narrow seams of blackband and clayband and from "balls" of ironstone brought down in working the coal. The only other source of supply in Scotland is the Middle Lias oolitic ironstone of the Isle of Raasay, of which the output was then about 1,300 tons a week and could not be increased materially on account of the limitations to its use for making basic pig on account of its low iron and high sulphur content, and inferior physical condition when calcined.

The production from Scottish ore was equivalent to an output of 2,000 to 2,500 tons per week of Scotch foundry, forge and basic pig or 25 per cent. of the total output of these makes in Scotland, the balance of the ore used being imported. After considerable discussion with the Coal Controller it was finally agreed in January, 1918, that an attempt should be made to stimulate the production of ironstone in the Scottish coalfield: (1) by allowing certain approved collieries working ironstone to count the latter as coal (at the rate of 1 to 3) for the purpose of the mine-owners' accounts with the Coal Controller; (2) by giving to the ironmasters an additional bonus of 5*s*. per ton on calcined ore used in the blast-furnaces over and above the tonnage used in the previous year (1917).

In the hope of finding some other source of supply for Scotch furnaces, a vein of manganiferous hematite ore in

Highland schists near the village of Tomintoul in County Banff was examined; but in view of the absence of any development and of the fact that much work of an exploratory nature would be required before the value of the deposit could be definitely ascertained, no prospect of an immediate supply was afforded in this direction.

The attention of the Department was drawn to the Redesdale ironstone which occurs in the Carboniferous limestone, 3 miles N.W. of Bellingham in Northumberland. This is a clay-ironstone occurring in bands of nodules through a 30-foot bed of shale of which it constitutes about 15 per cent. Mr. Merricks, who visited it in March, 1918, reported that in view of the preparatory work required to re-open the deposit no immediate increase of production could be looked for from this source and that in any case it was not a commercial proposition.

In Wiltshire deposits of iron-ore were examined in the Lower Greensand at Seend and in the top beds of the Corallian at Westbury. The Seend ore was found too siliceous and the Westbury ore to have too high a sulphur content to warrant the Ministry in allocating machinery and labour to work them. It was noted, however, that a proportion of the siliceous impurity of the Seend ore might be eliminated by screening.

In Ireland the present production, which averages about 400 tons per week, is confined to the pisolitic iron-ores of Antrim, which occur, in conjunction with ferriferous bauxite, interbedded with Tertiary basalts. Lieut. Butler examined these deposits in August, 1917, and reported that although the ores, on account of their low phosphorus content, can be used in limited proportions by hematite smelters, both on the east and west coasts of Great Britain, there is no demand for them for basic pig mixtures, on account of a high titanic acid content and because in most cases the ores cannot be delivered to the ironworks at a cost comparable with that of local ironstones.

Reports having reached the Department that valuable deposits of iron-ore exist in Ireland that could be easily

and quickly opened up, Mr. S. J. Lett spent some considerable time in the Spring of 1918 in an examination of their possibilities. In this connection the clay-ironstone beds near the base of the Yoredale Shales in the neighbourhood of Lough Allen and of the Arigna River in the Counties of Leitrim and Cavan appeared interesting. But although numerous, the individual beds are small, interrupted and separated by much intervening shale: in any case there was no possibility of an immediate production, even if work was to be started. Certain hematite beds in Upper Silurian rocks (Deehomet in County Down and Cleeragh in County Longford) were reported to be worth prospecting; but in view of the derelict condition of the old shafts, considerable preparatory work would be necessary.

It will be gathered that had there been no other sources available than those reviewed in the preceding pages, the prospects of carrying out the basic iron programme on home supplies of iron-ore would have been very poor. Fortunately for the country far better results had been shown to be obtainable from the Jurassic ironstones of the Midlands by Mr. Stephenson after a preliminary survey at the end of 1916. In his report he showed that a considerable augmentation of production was to be expected from this source and from Cleveland, provided the necessary labour and materials could be supplied. This view was confirmed after a more exhaustive examination in the Midlands by Mr. H. K. Scott. In Lincolnshire, Northamptonshire, Rutlandshire, Leicestershire and Oxfordshire considerable thicknesses of ironstone occur at slight depths below the surface, and the removal of the overburden exposes large quantities of ironstone that can be cheaply extracted by open-cast work or quarrying. Such conditions favoured an extensive application of machinery (steam-navvies, transporters, etc.) to the uncovering, digging and loading of the ironstone, whereby the output could be considerably increased without the necessity of making any large addition to the labour forces employed. It was decided, therefore, to instal diggers and transporters wherever possible; and these were obtained

from the makers without loss of time with the help of Mr. T. M. McAlpine, owners being allowed a rebate to enable them to meet the increased cost. The allocation of the diggers and other machinery to those places where they would be most advantageously employed was done on the recommendation of the Resident Engineers after an investigation on the spot of the special conditions of each case.

Particulars of these ironstones were given in a recent paper published by the Iron and Steel Institute.* Their average composition, as mined or quarried, is approximately as shown in the following table:—

AVERAGE COMPOSITION OF JURASSIC IRONSTONES AS MINED OR QUARRIED.

	Fe.	SiO_2.	Al_2O_3.	CaO.	S.	P.	Moisture.
	%	%	%	%	%	%	%
Cleveland	28·1	11·8	10·2	4·7	0·26	0·47	6·8
Northampton and Rutlandshire ...	32·5	14·7	6·1	2·7	0·10	0·60	15·2
N. Lincolnshire ...	22·7	8·1	5·1	18·2	0·16	0·31	10·7
Leicester and S. Lincolnshire ...	25·2	10·9	8·0	9·6	0·11	0·25	16·4
Oxfordshire	24·0	10·2	7·6	12·2	0·06	0·23	15·6

In order to be in a position to meet the increased demands of South Wales ironmasters, which it was anticipated would result from the carrying out of the basic iron programme, it was decided to assist production in Oxfordshire by building a standard gauge railway to connect with the Great Western Railway at Banbury. This railway was built, under contract, by the labour of German prisoners, to facilitate the development, near Wroxton north-west of Banbury, of a large area of Middle Lias ironstone of favourable composition for the manufacture of basic iron.

The allocation of increased supplies to blast-furnaces which had recently come into operation on basic pig-iron,

* Hatch, Journ. Iron and Steel Inst., vol. xcvii, 1918, p. 71.

or had been changed over from hematite, was, in those cases where no private contracts existed, arranged by the Mining Section, due regard being paid to the relative situation of furnaces and producers in order to minimise transport. In North Lincolnshire, Lord St. Oswald's quarries (The Frodingham Ironstone Mines Ltd.) were exceedingly useful in meeting the Ministry's increased demands. These quarries have an average output of 20,000 tons per week and of this about 25 per cent. was sent out of the district. Where long distance transport was unavoidable, for instance in sending ironstone from Northamptonshire to Middlesbrough or from Oxfordshire to South Wales, the importance of calcination at the source of supply was impressed upon producers; and as a consequence the output of calcined ore has been increased. Thus a quarry situated at Gretton near Corby in Northamptonshire has been worked for the supply of calcined stone since early in 1917 by the Lloyd's Ironstone Co., Ltd., with interned alien labour on behalf of the Ministry. The output of calcined stone at this quarry averaged 2,500 tons per week.

In order to prevent any abnormal rise in the selling price of ironstone in the Midlands, which at the beginning of 1917 had for a time been fixed at 3*s.* 3*d.* per ton, a maximum price, with a sliding scale based on the increases in the rate of wages, was fixed in January, 1918, by an order of the Minister of Munitions (the Midlands District Ironstone Control Order, 1918). The price fixed was 3*s.* 9*d.* per ton of raw ironstone at mine or quarry, plus ½*d.* for every sum of 1*s.* 3*d.* per week by which the rate of wages for the ironstone-getters was increased above the rate current on the 12th November, 1917. The areas to which this order applied were Rutlandshire, Leicestershire, Northamptonshire, north-east of a line drawn from Rugby to Buckingham, and Lincolnshire, south of a line drawn from Newark to Sleaford. For calcined ironstone in the same areas, the price was fixed at 9*s.* per ton, f.o.t. plus 1*d.* per ton for each 1*s.* per ton increase in the rate of wages. Subsequently on the 1st of July, 1918, the maximum price was raised to

10*s.* 3*d.* per ton, in order to meet the increased cost of coal. At about the same time the price of raw ironstone was raised 2½*d.* per ton to meet an increase in the price of stores.

In North Lincolnshire an agreement was entered into with the quarry owners in 1917 by which the maximum price was fixed at 4*s.* 9*d.* f.o.t. at the quarries, for all ironstone sent out of the district. At that price the Ministry had a call of 500,000 tons per annum. In Oxfordshire an agreement was come to with the owners early in 1918 fixing a maximum price of 3*s.* 6*d.* per ton of raw ironstone f.o.t. at the quarries. This was raised in August to 3*s.* 9*d.* on account of an increase in the rate of wages.

The demands of the owners for priority in the supply of machinery, plant and materials for the various works, necessitated by the development of the mines and the extension of existing, or the opening up of new quarries, required careful investigation by the Mining Section in order to ensure an equitable distribution of the restricted supplies. Only such applications as were found to be justified by the circumstances of each case received the support of the Mining Section and these were forwarded with a recommendation for favourable consideration to the Priority Department.

The returns of output bring out clearly the success of the work of the Mining Section in increasing the production of domestic ores. Comparing the average weekly production of the first half of the year 1918 with that of the year 1916, the increase in phosphoric ore amounted to 45,000 tons per week, equivalent to 2⅓ million tons per annum. Of this the Midlands accounted for 59 per cent., Cleveland for 26 per cent., Oxfordshire for 9 per cent., North Lincolnshire for 3 per cent., and other districts for 3 per cent.

Preparations had been made in the quarries for continuing these increases during the second half of the year, and had it been possible to carry out the basic iron programme by putting into operation the blast-furnaces arranged for, the necessary supplies of ore would have been forthcoming. Unfortunately the needs of the army at the front necessitated

calls on the industrial forces of the country which, by cutting off supplies of labour and fuel, effectually prevented this being done.

The outstanding fact to the credit of the Mining Section is that all demands for phosphoric iron-ore, however urgent, were met, and that at no time since its formation did any furnace have to go on slack blast for want of ore supplies.

With regard to manganese ore, it became necessary in consequence of the diminution in imports from abroad, to develop home supplies to as great an extent as possible. The only known sources were the low-grade silicate and carbonate ores of North Wales. During the war the output of the mines at Rhiw, near Pwllheli, on the Llyn Peninsula and in Merionethshire, was largely increased. The Ministry assisted by the provision of shipping (for the North Wales Manganese Co.'s ore) and road transport, by securing priority for machinery and by allocating the ore to the works most in need of it. Comparing the years 1916 and 1918 the production was trebled, as will be seen in the following table :—

HOME PRODUCTION OF MANGANESE ORE.

Year.	Tons.
1913	5,393
1914	3,437
1915	4,640
1916	5,140
1917	13,094
1918	14,942

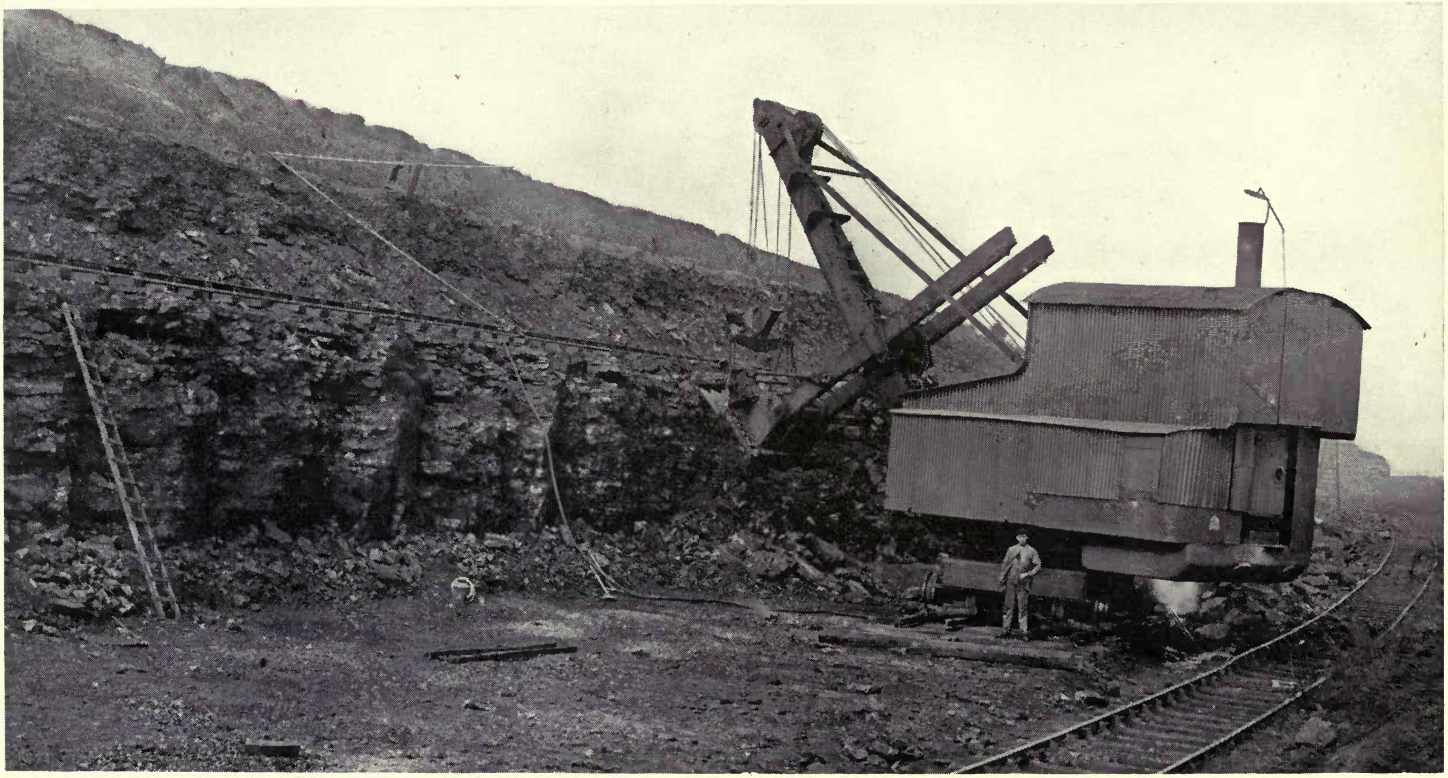

FIG. 11.—Navvy loading ironstone at the Midland Iron Co.'s Berkeley Quarry, North Lincolnshire. The cover is 3 feet thick, the ironstone 24 feet, the latter being worked in two benches by two separate navvies.

CHAPTER XI.

HOME PRODUCTION OF HEMATITE ORE.

When war broke out it was realised that there might be difficulty in securing sufficient hematite ore from Spain. This gave the Cumberland and Lancashire mines a considerable impetus; and many workings, which had been abandoned on the exhaustion of the best ore, were re-opened. But in such mines there were no reserves, and operations had to be confined to the extraction of pillars. Still, every effort was made to push production to the utmost, owing to the great demand for hematite ore.

The deposits occur in Carboniferous limestone, a formation which in this district rests unconformably on the old Skiddaw slates, and is itself concealed in places by overlying Coal-measures and Red Sandstones, or by Boulder-clay. The existing mines are situated between Lamplugh, in Cumberland, and Ulverston in Lancashire, a distance, from north to south, of 35 miles.

Already before the war extensive prospecting, by means of borings through the Red Sandstones, had disclosed, south of Egremont, some of the largest ore-bodies that have ever been found in either county, with the possible exception of that at the Hodbarrow mine. The Beckermet, Ullcoats and Ullbank Companies are now engaged in working these deposits.

While of varying iron and silica contents the West Coast ore is remarkably free from both phosphorus and sulphur; it therefore furnishes a pig-iron very suitable for the acid Bessemer process and yields an exceptionally pure steel. Most of the ore goes to local furnaces, of which the principal are those of the United Steel Co., Ltd., the Whitehaven

Hematite Iron and Steel Co., Ltd., the Barrow Steel Co., Ltd., the North Lonsdale Hematite Iron Co., Ltd., and the Carnforth Hematite Iron Co., Ltd.

Besides the blast-ore, which constitutes 98 per cent. of the total ore mined, and is consumed locally, there are two other classes of ore which are sent out of the district, mainly to the Midlands. These are "lumpy ore," which is an exceptionally pure hematite used for oxidising purposes in the Siemen Martin's process, and "annealing ore," a graded material, free from dust and of about pea-size, which is obtained by screening, with or without washing. It is used in the manufacture of malleable castings.

As received at the works the blast-ores at present mined range in composition between the following limits :—

	Per cent.	Per cent.	Average.
Iron ...	40	57	50
Silica ...	6	23	13
Phosphorus	0·005	0·022	0·009
Moisture ...	4	9	5·6

There are 21 mining companies operating in Cumberland, with an average output, during 1917, of 24,200 tons per week. In Lancashire there are five companies, with an average output, during 1917, of 6,300 tons per week.

The production for the last ten years is shown in the following table :—

PRODUCTION OF HEMATITE ON WEST COAST.

Year.	Cumberland.	Lancashire.	Total.
	Tons.	Tons.	Tons.
1908...	1,155,501	293,619	1,449,120
1909...	1,246,228	312,367	1,558,595
1910...	1,334,751	408,090	1,742,841
1911...	1,272,626	439,475	1,712,101
1912...	1,207,981	360,446	1,568,427
1913...	1,360,924	406,155	1,767,079
1914...	1,295,804	334,860	1,630,664
1915...	1,323,398	333,086	1,656,484
1916...	1,310,366	297,949	1,608,315
1917...	1,256,393	330,036	1,586,429
1918...	1,229,231	320,731	1,549,962

The number of men employed at the end of 1918 was, in Cumberland—5,384, and in Lancashire—1,391, making a total of 6,775. The mines vary considerably in size, and consequently this labour is very unequally distributed among them. Thus, in March, 1918, five mines, namely Hodbarrow, Beckermet, Kennedy, Ullcoats and Bigrigg, employed 3,250 men and produced 19,100 tons per week out of a total production of 33,000 tons. The efficiency measured by the tonnage produced per man employed per day was over 1 ton for these five mines; whereas for the whole number of mines it averaged 0·8 ton. The relation of these five to the whole number of mines in respect to labour and output is shown in the following table :—

Number of Mines.	Labour Force Percentage of Total.	Output Percentage of Total.	Efficiency per Man Employed, per Day.
5	44·5	58·3	Above 1 ton
17	45·9	37·0	0·5 to 1 ,,
8	9·6	4·7	Under 0·5 ton
30	100·0	100·0	0·8

The working costs of the Cumberland and Lancashire mines before the war, in 1914, averaged from 12*s.* to 13*s.* per ton. In March, 1918, they averaged 28*s.* 10*d.* per ton; for Cumberland alone they averaged 29*s.* 3*d.*, and for Lancashire 26*s.* 11*d.* The average costs of Cumberland and Lancashire mines for 1914 and for March, 1918, when distributed under the chief heads of expenditure, give the following results :—

	1914.		1918.	
	s.	*d.*	*s.*	*d.*
Wages	5	10·64	15	2·74
Materials	1	11·75	4	7·71
Royalties	4	11·26	6	7·02
Administration ...			1	1·77
Other charges ...			1	2·44
	12	9·65	28	9·68

The ore is got by so-called "companies" of miners who take a contract or "bargain" from the management at

a price estimated to yield each member of the "company" the "ascertainment wage," which is fixed at 11*s.* 3*d.* per shift plus bonuses. The bargains are made for a fortnight; should the individual share be less than the "minimum wage" at the end of the fortnight, it is "made up" to that figure by the management. Previous to Sir W. N. Atkinson's award in March, 1918 (see page 86), and since February, 1917, the minimum wage had been fixed at 9*s.* 6*d.* It is now 11*s.* 3*d.* (end of 1918).

The system under which the men are employed in Cumberland and Lancashire differs in some particulars. In Cumberland, for instance, the "companies" are small, generally consisting of two to 12 men. The work of "trailing" (*i.e.*, tramming the ore from the working faces to the shaft) was until 1917, done by young men and boys, who, when vacancies occurred, were given positions as miners. This was changed in August, 1917, when about 700 of these labourers were promoted to miners' status, although they still did the trailing. Hodbarrow, although in Cumberland, adopts the Lancashire system, in which the actual work of ore-getting is performed by larger "companies" of men, 26 and 28 in number, who participate on equal terms in the work and in the proceeds derived therefrom; for instance, the "trailers" are paid the same wages as miners.

Before the war the wages of the workmen were fixed by sliding scale based on the price of pig-iron. They had the following range :—

WAGES—UNDERGROUND.

	s.	*d.*	*s.*	*d.*	
Miners	6	0 to 6	6		per shift of 8 hours.
Leading labourers ...	3	6 to 5	6	,,	,, ,, ,,
Boy labourers ...	1	9 to 4	6	,,	,, ,, ,,
Shiftmen	4	0 to 6	9	,,	,, ,, ,,

WAGES—SURFACE.

Joiners	5	1 to 6	3	per shift of 9 hours.	
Blacksmiths	5	3 to 7	0	,,	,, ,, ,,
Fitters	5	6 to 8	4	,,	,, ,, ,,
Enginemen	5	9 to 6	9	,,	,, ,, ,,
Banksmen	4	6 to 5	6	,,	,, ,, ,,
Labourers	2	6 to 4	9	,,	,, ,, ,,
Boy labourers ...	1	0 to 2	9	,,	,, ,, ,,

On the fixing of the price of pig-iron by the Ministry of Munitions, the automatic rise in the men's wages which normally would have followed the general rise in prices, ceased to operate. This, and closely related circumstances, led to industrial disturbances that affected the output adversely.

Prior to the war, labour grievances had been dealt with by Conciliation Boards, of which there were five in the West Cumberland district. Though never actually dissolved, they were considered to be in abeyance for the period of the War, and labour troubles were dealt with by the Ministry of Munitions in London.

The first important move on the part of the Cumberland Miners' Association was the securing from the Labour Department of the Ministry of the payment of a flat rate of 14*s.* per shift for the August Bank Holiday in 1916. This was negotiated by Mr. T. Gavan Duffy, the Secretary of the Association, and it proved a powerful lever in his subsequent negotiations with the Ministry.

In February, 1917, an award was made by the Labour Department, raising the minimum wage of Cumberland iron-ore miners from 7*s.* 6*d.* to 9*s.* 6*d.* per shift, and giving a war-bonus of 5*s.* per week or 10*d.* per shift granted. It was also decided that men who had worked as miners previous to the War and were still competent to perform a miner's work, should, no matter what their present employment, be given the corresponding status and pay, on the plea " once a miner, always a miner." This award of the Ministry proved anything but easy to carry out, and in the case of old pre-war miners, who on account of age or infirmity had been given light work at the surface, it led to many disputes.

During this period proposals for bringing into the mines men from other districts were under discussion. Camps suitable for their accommodation had already been erected at Egremont, Frizington, Bigrigg and Haverigg in Cumberland and at Askam in Lancashire. But, before taking definite steps in this direction the Ministry decided to obtain the release of any local iron-ore workers then serving with the

Home Forces. The return of those serving abroad was more difficult to arrange.

On the 1st of March, 1917, Mr. W. Selkirk was appointed Resident Engineer and established his headquarters at Whitehaven, with Mr. C. D. Wilkinson as Technical Assistant and Mr. R. de R. Gye as Secretary. He at once set about devising ways and means for increasing the production of the mines, which by the beginning of 1917 had fallen to a low level.

The proposal to import labour into the district met with some opposition from the miners; and the claims of the Cumberland Miners' Association were formulated in a letter sent by their agent, Mr. T. Gavan Duffy, to the West Coast Iron Ore Proprietors' Association on the 11th of June, 1917. The demand made was that no miners, other than those belonging to the district, should be given work until all labourers over twenty-one years of age and with three years' experience had been promoted to the status of full miners. An increase of wages for winding enginemen, tradesmen working on the surface and shiftmen was also requested. Local strikes at Hodbarrow and at other mines ensued; and, although these were settled, the Miners' Association on the 4th of July gave a fortnight's notice of their intention to strike and to remain on strike until the Association's demands regarding the minimum wage had been complied with and an undertaking given that, before outside labour was imported, all local men should be found work.

At this juncture the Ministry of Munitions decided to take over the control of the Cumberland and Lancashire mines; and this was done by proclamation on the 26th of July, 1917, Sir John Hunter being appointed Controller of the mines with Mr. W. Selkirk, Deputy Controller in Whitehaven.

On the 13th of August the men employed in the Cumberland mines came out on strike. On the 24th, Mr. Gavan Duffy, representing the Cumberland iron-ore miners, met the Minister (Mr. Churchill) and Mr. Kellaway in London;

and after prolonged discussion an agreement was reached, the principal points of which were: (1) that the leading labourers, estimated at 700, should receive the miners' rate of wages, their places being filled by the promotion of an equal number of ordinary labourers to leading labourers; (2) that all workers, whether on surface or underground, other than miners, should receive an advance of one shilling per shift; (3) that all boys under 16 years of age should receive an advance of 6*d.* per shift; and (4) that the men should receive a bonus of 1*s.* per week for every 1,000 tons of ore raised over 27,000 tons, the bonus to be raised to 2*s.* when the output reached 35,000 tons per week, while a minimum production bonus of 5*s.* per week was guaranteed on the expiration of three months.

The men returned to work on the 27th of August; but on the 17th of September, 1917, the Lonsdale men again came out on strike, demanding a minimum wage of 11*s.* 3*d.*; this was settled by Mr. Selkirk on the 26th without raising the minimum.

A party of delegates, headed by Mr. David Gilmour of the Ministry of National Service, visited the mines and hutments, on the 16th of October, to make arrangements for the introduction of Scottish coal-miners. Ultimately 542 of these miners were brought into the district and distributed among the different camps. Their pay was fixed at a flat rate of 11*s.* 3*d.* per shift, plus war bonus and subsistence allowance. Owing to misunderstandings regarding these arrangements the introduction of Scottish miners did not prove an unmixed blessing. In the course of the year 1918 many of them drifted back to their previous occupation; and those under 23 were called up to the Army. By October, 1918, only about 100 remained, and they returned to Scotland in December, when the Ministry of National Service decided to withdraw the subsistence allowance.

At the end of January, 1918, Mr. Selkirk, who by the beginning of December, 1917, had succeeded in raising the output to close on 40,000 tons per week, resigned his position and Mr. W. T. Anderson, till then Chief Technical Adviser

to the Mineral Resources Department of the Ministry of Munitions, was appointed Controller on the 27th of January, 1918, with Mr. MacLachan as Deputy Controller (Labour). Mr. C. D. Wilkinson was appointed Deputy Controller (Production) on the 1st of March, 1918.

Immediately on his appointment Mr. Anderson instituted a Conciliation Committee and an Arbitration Board, the formation of which had been under consideration by Mr. Selkirk. They superseded the five Conciliation Boards previously existing and referred to on p. 83.

On the 13th of March, 1918, the Conciliation Board sat, under the neutral chairmanship of Sir W. N. Atkinson, to consider the claims of the Cumberland miners for an increase of the minimum wage. Sir W. N. Atkinson's award was given on the 20th of March : by this the minimum rate for miners was increased to 11*s.* 3*d.* per shift ; while the wages of surface workmen (other than winding enginemen), over 18 years of age, was increased by 6*d.* per shift, under 18 years, by 3*d.* per shift.

A similar award was at once asked for by the Furness Iron Mines and Quarrymen's Union, and on the 8th of May the Controller increased the minimum rate for miners from 9*s.* 4*d.* to 11*s.* per shift ; enginemen received 8*d.* per shift, surface workers (other than enginemen) over 18 years of age, 6*d.* per shift, under 18 years, 3*d.* per shift.

Under the Schedule of Protected Occupations (M.M. 130) which came into force on the 1st of May, 1917, all underground workers in iron-ore mines were exempt from military service. A revision of this early in 1918 provided *inter alia* for the calling up of iron-ore workers under the age of 23. Men of 18 and 19 years of age had already been called up to serve with the Colours, when on the 4th of June an attempt was made through an unofficial strike to coerce the Government into abandoning the project. Arrangements were made for proclaiming this strike ; but on the Controller issuing to each man's home a personal appeal explaining the situation, the men returned to work and there was no further trouble in this matter.

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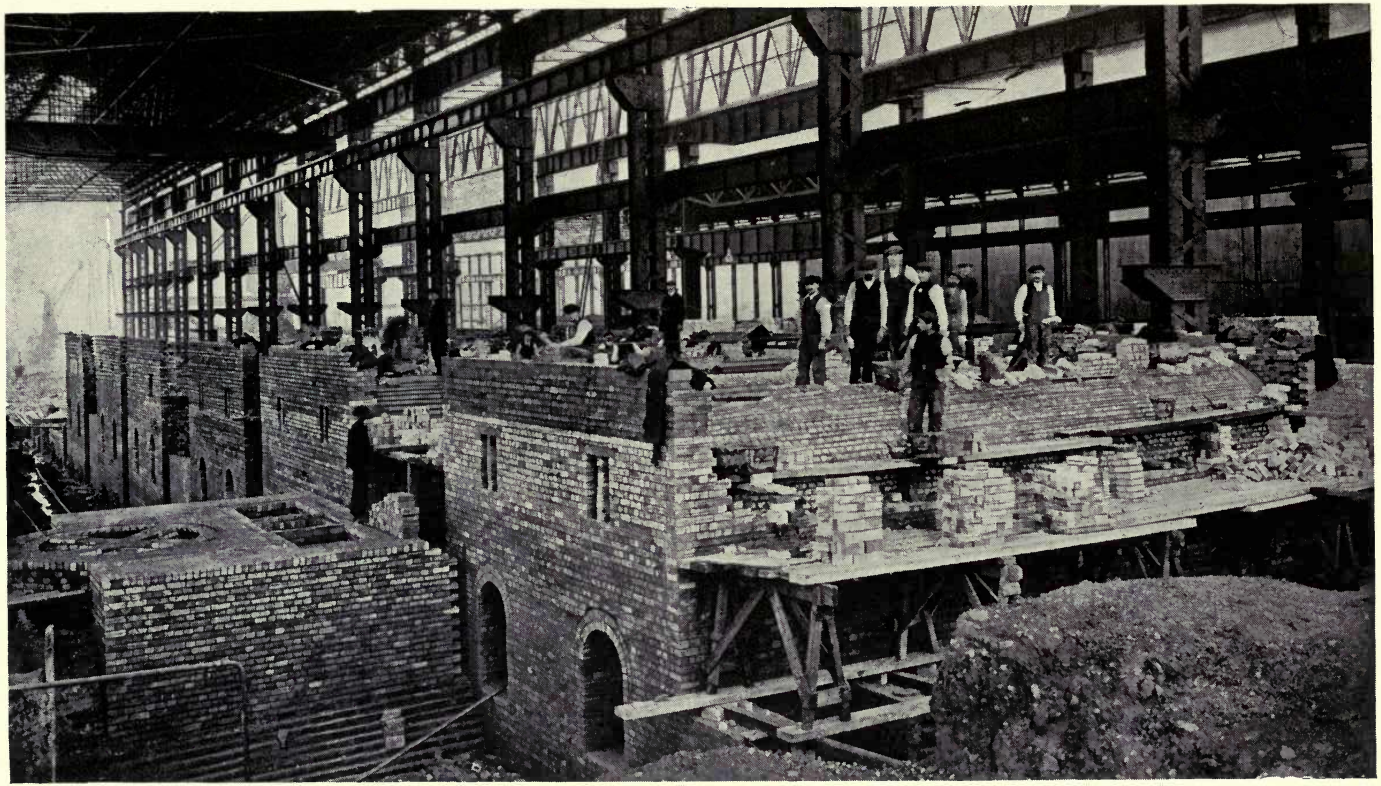


FIG. 12.—Extension to William Beardmore & Co.'s steel-works at Mossend, near Glasgow. New open-hearth furnaces.

The rate of wages obtaining at the end of 1918 was as follows :—

WAGES—UNDERGROUND

	s.	d.	
Miners	11	3	(minimum) per shift plus 1*s.* 8*d.* bonus.
Leading labourers ...	7	6	per shift plus 1*s.* 8*d.* bonus.
Boy-labourers ...	4	0	,, ,, ,, ,, ,,
Shiftmen	11	3	,, ,, ,, ,, ,,

WAGES—SURFACE.

Joiners	9	0	per shift plus 1*s.* 8*d.* bonus.
Blacksmith	9	0	,, ,, ,, ,, ,,
Fitters	9	0	,, ,, ,, ,, ,,
Enginemen	8	9	,, ,, ,, 2*s.* 6*d.* ,,
Banksmen	8	0	,, ,, ,, 1*s.* 8*d.* ,,
Labourers	6	6	,, ,, ,, ,, ,,
Boy-labourers ...	3	3	,, ,, ,, ,, ,,

CHAPTER XII.

FOREIGN ORE.

In August, 1914, prices for imported iron-ore were low, owing to the general depression that prevailed prior to the commencement of hostilities : best Bilbao Rubio was 17*s.* 6*d.* per ton delivered in the United Kingdom, with a freight of about 4*s.* per ton. As soon as war was declared, an advance to 21*s.* per ton, delivered in the United Kingdom, took place ; but the diversion to this country of cargoes *en route* for Germany, and their sale for what they would fetch, lowered prices. The demand being restricted, the rate of freight fell ; and there was no pronounced movement of recovery until the end of the year, when it was recognised that the war was likely to be a long one, and freights began to rise sharply.

Early in 1916, the position had become so acute that it was feared that it might become impossible to maintain supplies from abroad. The continued fluctuation in the prices of iron and steel made it desirable to have some firm ground, and it was generally recognised that the only way in which stabilisation could be secured was by the provision of raw materials at fixed rates.

In March, 1916, when freights had risen in Middlesbrough from about 4*s.* to 28*s.*, Sir Leonard W. Llewelyn, Colonel Carmichael, Mr. MacLellan and Mr. Lysaght convened a meeting of ore-merchants, representative of the different districts, to decide what steps should be taken to meet the situation. A scheme was framed, the principal feature of which was the establishment of a uniform parity (or basis) rate of freight, from Bilbao to the United Kingdom, of 17*s.*

per ton with certain modifications according to the port of loading. This rate of freight was double that which had ruled in pre-war times during an active period. An Official Ore-Broker, with an office in London, was appointed, and in him the entire chartering of all ore-tonnage was centred. For a time the result was that actual freights fell and the parity rate was not far removed from the real rate. Ironmasters were assured of ore on the basis of 34*s.* per ton for best Bilbao Rubio, delivered in the United Kingdom, and containing 50 per cent. iron as received, with a sliding scale of 6*d.* per unit of iron, up or down, and 8 per cent. silica with a penalty up, and allowance down, of 1½*d.* per unit, this being 17*s.* for freight, and 17*s.* for ore and other charges. But the effect of the war was speedily shown both on producing costs and on sea and war risks; and from 34*s.* the price rose to 38*s.*

During this period the standing committee of representative iron-ore merchants had from time to time been consulted by the Ministry. In September, 1916, Sir John Hunter, finding it necessary to devise a new organisation that would give the Ministry greater control, thanked the committee for its services and dissolved it. He then appointed Mr. F. L. MacLeod Official Adviser on Foreign Iron Ore to the Section of which Captain R. J. Wallis-Jones was in charge, and set up local committees of ironmasters in South Wales, in Whitehaven, in Middlesbrough, and in Scotland. Two representatives from these four districts were formed into a Central Iron Ore Committee, sitting in London under the Chairmanship of Mr. MacLeod, who represented the Ministry and had the right of veto.

An advance of 3*s.* per ton—bringing the price of Standard Bilbao Rubio up to 41*s.*—was made on the 17th January, 1917, and the War Risk Insurance was fixed at two guineas per cent.

Previous to Mr. MacLeod's appointment, an approved list of merchants authorised to trade in iron-ore had been drawn up by the original committee, the cardinal principle being that the state of affairs that had existed for the six

months prior to March 1916, should be the governing factor, and that merchants, who had dealt in certain markets, were to be confined to those markets, thereby preventing competition and giving the Ministry a firm control over the entire supply. It had been further decided that all merchants on the approved list were to be resident in the United Kingdom, and that only these were to be supplied by the Official Ore Broker with steamers for the conveyance of ore to the United Kingdom. On this basis business had been, and continued to be conducted fairly smoothly until early in 1917, when the shortage of coal in Spain made it desirable to obtain greater supplies from England. To bring this about, a Spanish Royal Order was issued to the effect that all vessels loading iron-ore were, on their return journey, to carry coal cargoes, amounting to 150,000 tons per month. The consequent delay to shipments created so serious a situation that in March, 1917, the Spanish Government was compelled to send over a Special Envoy (the Marquis de Cortina) to negotiate an agreement.

The Ministry of Munitions had a very material interest in any commercial agreement with Spain, since, not only was the United Kingdom drawing from that country its main supply of iron-ore, but also the pyrites necessary for sulphuric acid manufacture, not to speak of copper, lead, etc. The Foreign Office took charge of the negotiations and Sir Maurice de Bunsen on its behalf directed them throughout, the various Ministries sending representatives to an Advisory Committee. Towards the end of the negotiations Mr. MacLeod was asked to meet the Marquis de Cortina, and with his assistance an agreement was reached. Unfortunately, before the text could be translated and the document signed, the Spanish Government fell, and the new Government refused to ratify.

Supplies of iron-ore were, however, not directly interrupted, and the Royal Order compelling a return cargo of coal was not put into force, although it remained a standing menace to the situation. The new Government opened up discussion through the Spanish Ambassador in London,

and after months of negotiation Sir Maurice de Bunsen again called in Mr. MacLeod to meet the Ambassador, and an agreement was finally signed on the 29th May, 1918. This agreement has undoubtedly contributed to the maintenance of friendly relations between the two countries, and has relieved the Ministry of any further anxiety in regard to the supply of very important raw materials.

In January, 1918, the price for supplies was raised 2*s.* 6*d.* per ton, bringing the standard for Best Bilbao Rubio to 43*s.* 6*d.* The Spanish Exchange soon began to give trouble. Ruling before the war at about 27 pesetas, it had by the middle of April, 1918, fallen to 15.95, as against a gold parity of 25/22½. To meet the situation it was agreed, on the 1st April, 1918, that, as long as the Exchange was below 19.50, compensation should be given to bring it up to this point. That this step was a wise one, as compared with the alternative of further raising the sterling price, was evidenced when the success of the Allied Arms towards the end of August, 1918, put the Exchange above the level indicated.

The other important country from which iron-ore is drawn is Sweden. In December, 1916, the Ministry through Mr. MacLeod carried through a direct contract with the Grængesberg Company, the owners of the famous Gellivare and Kiiruanavarra iron-ore fields, for the supply of one million tons of ore. This secured for the basic steel industry the high-grade ore necessary for oxidising purposes.

In May, 1918, the associated Governments of France, the United States, and the United Kingdom negotiated an agreement with Sweden, the guiding principle of which was that the Swedish Government should divide its export of iron-ore equally between the Central Powers and the Associated Governments. This was a blow to the German steel industry, since prior to the war, of a total output of 6,439,750 tons, 5,005,235 tons, or close on 80 per cent. went to Germany, or to Holland for transhipment to Germany. Mr. MacLeod was asked by the Foreign Office to negotiate a contract for 2,000,000 tons, and on its conclusion, received a letter from Commander F. Leverton Harris, Under-Secre-

tary for Blockade, Foreign Office, expressing appreciation of the able manner in which he and those helping him had conducted the negotiations. Mr. MacLeod was assisted in this work by Captain Wallis-Jones.

The activities of the Foreign Ore Section may be thus briefly summarised: in spite of the German submarine campaign, by which the late Chancellor Bethmann-Hollweg stated he would cut off iron-ore and foodstuffs from the United Kingdom, a continuous supply of foreign iron-ore has been maintained. For a period, when coal and food supplies from the United Kingdom were sent direct to Italy, Mediterranean sources of iron-ore had to be mainly drawn on; but, more recently, when, in consequence of coal being sent from France to Italy, there was not the same return tonnage available for the iron-ore ports of the Mediterranean, supplies were drawn principally from the North of Spain. It must also be recorded as a noteworthy fact that the f.o.b. price at which the ore was obtained was throughout a most reasonable one. On this subject Mr. Herbert Guedalla in his report to the Minister, dated 29th July, 1918, on iron and steel subsidies wrote:—"Even taking into consideration the fact that imports of this ore (hematite) into Germany have stopped, the highest credit is due to the organization dealing with this matter for having kept the price in Spanish currency at what is practically the pre-war level."

In February, 1917, a Commission representing a consortium of British iron and steel masters visited the iron-ore fields of North-West France, with a view to the utilization of the phosphoric iron-ores of these districts in British blast-furnaces in connection with a proposed exchange as between Great Britain and France of coal and iron-ore.

The Commission, on which the Board of Trade and the Ministry of Munitions were represented by Dr. F. H. Hatch, reported that the Normandy and Brittany ores would be suitable, to a limited extent, for admixture with some British ores; for although the calcined ore is higher in silica than Cleveland, the alumina is somewhat lower, and the iron-

content higher. Their use in the various districts is almost entirely a question of cost, and greatly depends on available means of water-transport. As regards the Briey field, it is doubtful at present whether this ore could be introduced into England at a sufficiently low figure ; but the canalisation of the Meuse would alter the position. The average composition of these ores is represented by the following figures :—

	Normandy.	Brittany.	Briey.
	Calcined Carbonate Ore.	Calcined Carbonate Ore.	Ore as Mined.
	Per cent.	Per cent.	Per cent.
Metallic iron	44–50	51–54	33
Manganese	1	0·25–0·3	—
Silica	12–21	11–14	6
Alumina	7–8	5	—
Lime	2½–4	2–3	16
Manganese	2	—	—
Sulphur	0·04	—	—
Phosphorus	0·65–0·85	0·75–0·90	—

The attention of the Commission was also directed to the hematite ore available in the French possessions of North Africa, especially in regard to the Ouenza mine. The suitability of these high-class ores for the British market has been definitely established.

CHAPTER XIII.

FUEL.

The Coal and Coke Section of the Ministry under Mr. P. G. Lewis was formed at the end of December, 1915. At that time several blast-furnaces had been put on slack blast owing to the inadequate supply of coke. In order to be in a position to deal with this and generally with the increasing shortage of the coal required for various munition purposes, it was decided that it would be necessary to control prices. In January, 1916, therefore, maximum prices were fixed for metallurgical coke in Scotland, Durham, South Wales and the Midlands, the latter area including for the present purpose Lancashire and Yorkshire. Subject to certain adjustments, made from time to time, the system then arranged has continued in force from January, 1916, to the present date (end of 1918); and, on the whole, it has worked extremely well.

The production and distribution of metallurgical coke was complicated by its fluctuating price. At the outbreak of war there was a serious glut of this material. This brought about a great fall in price, and the coke was, in many cases, actually sold at a figure equal to the cost of the coal put into the ovens, with consequent heavy losses to the makers. The production of pig-iron had rapidly decreased in 1914, while the output of coke was increasing owing to the introduction of by-product ovens. But in the early part of 1915 a considerable number of inefficient ovens of the beehive type were put out of operation; and this and the extra demand for coke, owing to the increased manufacture of pig-iron for munition purposes, caused a rapid advance in

price. The production of large quantities of benzol and toluol required for war purposes soon reversed this position, so that by September, 1915, a committee had to be appointed by the Explosives Department of the Ministry to advise on measures for the disposal of the surplus coke produced in the manufacture of these materials. This committee made a number of valuable suggestions; but before their report

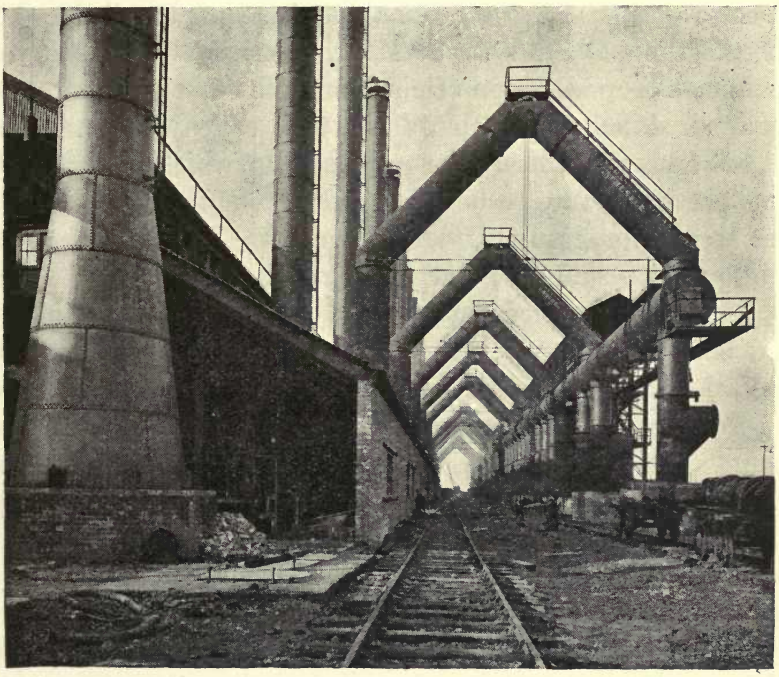


Fig. 13.—Extension to William Beardmore & Co.'s steel-works at Mossend, near Glasgow—Gas-producer plant.

was published the position had been again entirely changed by the shortage mentioned at the beginning of this chapter as occurring in December, 1915. It was accentuated by large demands from France and Italy, amounting in the aggregate to over a million tons per annum. Consequently the newly formed Section had to face a complicated situation at a time when coke-makers were quite unable to understand the meaning of such violent fluctuations, and had lost confidence in the future of their industry.

The new Section at once made arrangements with the War Trade Department and the Coal Exports Committee, by which a system of licences for the export of coke was introduced. Urgent appeals were also issued to all coke-makers to increase their production as rapidly as possible, and by the end of March, 1916, current requirements were being met.

During the next six months, detailed plans were formulated to meet the large additional requirements entailed under the programme laid down by Mr. Hall and Mr. Walmsley for the increased production of pig-iron. The first printed programme, dated the 27th June, 1916, called for an extra 39,546 tons of furnace-coke per week, of which over 21,000 tons per week were to be furnished in four months. Under the second programme, dated the 30th September, 1916, this quantity had been increased to 53,462 tons per week, representing the needs of over 57 blast-furnaces, which it had been arranged with the owners should be brought into operation as quickly as possible, chiefly to produce basic pig-iron from home ores. Unfortunately, these arrangements entailed demands for coke on collieries situated in the Midlands, where the output of coking coal was already short, and was being steadily further reduced by the recruitment of coal-miners for the Army. Owing to the necessity of furnishing coke to the blast-furnaces at a reasonable price, it was not possible to bring coke to the Midlands from South Wales or Durham, where adequate supplies of coal suitable for its manufacture could be obtained.

The whole of the year 1916 was devoted to organising production on a rapidly increasing scale and under conditions that would at the termination of hostilities enable pig-iron and steel to be produced at a price permitting competition with other countries.

Owing to the lack of confidence above referred to, difficulty was experienced in persuading owners of coke-ovens to increase their plant. At the end of 1916, the shortage of shipping affected the supply of imported hematite iron-ore, with the result that blast-furnaces that had been listed for

the manufacture of hematite pig-iron had to be diverted to basic pig-iron. This led to a further demand on collieries producing coking coal, which was most difficult to satisfy under conditions of efficient commercial practice.

Various expedients were adopted to meet the situation, the chief of which was an increase in the output per oven by the use of higher temperatures, and, in some cases, by the reduction of the moisture in the washed coal charged into by-product ovens. By these means the average output of coke per oven was in the year 1916 raised to 1,320 tons per annum as compared with 1,133 in 1915—an increased efficiency of 17 per cent. A considerable amount of labour and cost was thus avoided, apart from the saving of the time which would have been required to build additional batteries of ovens. Time being an important factor, it was also found necessary to repair and put into operation over 800 beehive ovens, which had been abandoned. The result of these measures may be seen in the following returns of output during the war period :—

OUTPUT OF METALLURGICAL COKE.

Year.	Tons.
1914	11,050,000
1915	12,137,000
1916	13,422,000
1917	13,862,000
1918	13,301,548

It will be seen that the output for 1917 shows an increase of $2\frac{3}{4}$ million tons (equivalent to about 25 per cent.) over that for the year 1914. To furnish this increased production more than four million tons of coal per annum was forthcoming, notwithstanding the loss in output caused by the recruitment of miners. The quantity of coke exported during the year 1916 was 1,130,000 tons, of which 65 per cent. was exported to France and 15 per cent. to Italy, the remainder being sent to neutral countries in exchange for copper, lead, and other important munition commodities. In 1917 the export fell to 879,000 tons and in 1918 to 635,000 tons.

The home consumption of metallurgical coke for the last four years has been as follows :—

CONSUMPTION OF METALLURGICAL COKE.

Year.	Tons.
1915	11,515,000
1916	12,292,000
1917	12,923,000
1918	12,667,000

The consumption of coke in blast-furnaces in the United Kingdom during 1917 was 11,140,000 tons.

During the war period over 1,750 by-product coke-ovens were laid down at a cost of nearly £5,000,000, to which the Ministry contributed £1,250,000. It is anticipated that the total output of coke from these ovens will be about 16½ million tons per annum, when the plants are in full operation—approximately a 50 per cent. increase upon the pre-war output. This increase in the production of coke will require 8¼ million tons additional coal per annum, representing the labour of 33,000 coal miners. The total quantity of coal that will then have to be carbonised for the manufacture of metallurgical coke will be 30 million tons per annum, or 11 per cent. of the pre-war total output of coal in the United Kingdom.

Metallurgical coke was produced in 1917 in the following districts and in the proportions given :—

DISTRICTS PRODUCING METALLURGICAL COKE.

District.	Percentage Ratio to Total Production.
Durham	39
Yorkshire	26
South Wales	12
Shropshire, Staffordshire and Worcestershire	5
Derbyshire, Lincolnshire and Nottingham ...	5
Lancashire and Cheshire	5
Cumberland	4
Scotland	4
	100

Furnace coke (amounting to 80 per cent. of the total production of metallurgical coke) was consumed in 1917 in the following districts and in the proportions given :—

DISTRICTS CONSUMING FURNACE COKE.

District.	Percentage Ratio to Total Production.
Cleveland, Durham and Northumberland ...	36
Midlands, including South Yorkshire ...	24
Cumberland	14
Shropshire, Staffordshire and Warwickshire	9
South Wales	8
Lancashire, Cheshire and North Wales ...	5
Scotland	4
	100

Efforts have been made to reduce the output of beehive coke and to replace it by by-product coke as rapidly as practicable, on account of the saving of coal thereby effected. At the present time, 80 per cent. of the production of metallurgical coke is obtained from by-product ovens, 16 per cent. from beehive ovens, and 4 per cent. from the non-recovery Coppée retort-ovens. In the year 1913, 58 per cent. only was made in by-product ovens, with the result that not only were the valuable by-products lost, but there was a serious additional loss from the cost of the extra labour and coal. In 1913, 13,167 beehive ovens were in operation ; in October, 1918, this number had been reduced to 6,399. As a result of this change the same amount of coke is produced with a saving of over 800,000 tons of coal per annum. The resulting by-products were during the war at the disposal of the Department of Explosives Supplies. It may be of general interest to know that they comprised the following commodities :—

Material.	Output per Annum.
Sulphate of ammonia (the present price of which is about £18 per ton)	165,000 tons
Crude benzol (the price of which is 11*d.* per gallon)	34,000,000 gallons
Crude tar (the price of which is 30*s.* per ton)	450,000 tons

The total value of crude by-products obtained, at the present controlled prices, exceeds £4,500,000 per annum, the value of the coke output being about £24,000,000 per annum. The number of ovens in operation on the 31st October, 1918, was: by-product—8,375; retort—1,334; and beehive—6,399.

In Scotland, where a large proportion of the fuel used in the blast-furnaces is splint, or hard coal, the tar, ammonia and other constituents of the coal are recovered as by-products.

According to present practice in Scotland, the average consumption of fuel per blast-furnace is 504 tons per week, of which 79 per cent. is splint, or hard coal, 16 per cent. furnace coke, and 5 per cent. gasworks char. The total consumption of fuel for the 92 blast-furnaces at present in existence would amount to 46,000 tons per week, and for the 27 new furnaces, which would be required to balance the steel-making capacity (see p. 25), 13,600 tons of fuel would be required in addition, making a total of 59,600 tons per week. The Scottish Advisory Committee reported that coal for the new furnaces could be provided during the war; but in consideration of the limited reserves of splint coal, it was obvious that this supply could not be for long maintained under economic conditions. The following is a summary of the Committee's report:—

The output of metallurgical coke in Scotland at the end of December, 1916, averaged 10,265 tons per week, 20 per cent. of which was made in beehive ovens and 80 per cent. in by-product ovens. It is, therefore, clear that in order to provide for the 27 new blast furnaces, referred to, it would be necessary to erect 50 new by-product coke-ovens.

In order to study the possibility of substituting coke for splint coal in working new blast-furnaces, an enquiry into the coking coal seams of Scotland was carried out for the Ministry of Munitions by the Advisory Committee. Coal owners were asked to make returns of the quantities available and to send samples of their coking coal for examination to the Technical College, Glasgow. The samples, to the number of 367, were examined by Professor Gray, and

for the purposes of his report the following classification was made :—

Description.	Caking Index.	Number of Samples.
Coals unsuited for coke-making	below 11	208
„ possibly suitable for mixing	11	33
„ suitable for mixing	12 to 14	59
„ possibly suitable for making coke ...	15	8
„ suitable for the manufacture of coke ...	16 and over	59
Total number of coals examined		367

With regard to the sulphur and phosphorus contents, the coke made from these coals will contain one-half of 1 per cent. and upwards of sulphur; while in most of the coke the phosphorus is not sufficiently high to militate against its use in the manufacture of hematite pig.

With regard to quantities, the Committee was of the opinion that the reserves in Scotland of good coking coal (that is with a caking index of 16 and over) were not less than 80,000,000 tons. According to present practice, this class of coal is separated by screening into *large coal* for gas making or navigation purposes, and *small coal*, which can be used for coking. Before coking, the small coal is washed and crushed. The yield of good metallurgical coke is 60 per cent. of the small coal or 30 per cent. of the coal as mined. On this basis the 80,000,000 tons would yield 24,000,000 tons of good metallurgical coke.

The present output of Scottish coke is about 10,000 tons per week, or say 550,000 tons per annum, of which, at the time the Committee's report was made, 70 per cent. was used for blast-furnaces and 30 per cent. for other purposes and export. In order to keep 119 furnaces in blast an additional 140,000 tons per annum would be required, making the total requirements for all purposes 690,000 tons per annum. On this basis the 24,000,000 tons of furnace coke would be consumed in about 55 years, provided the make of furnace coke was not increased by coking some of the large coal.

No doubt the use of gas char or inferior coke will be increased, but it is obvious that the known reserves of coking coal do not appear to warrant the erection of many large modern blast-furnaces using coke alone.

The rapid depletion of the Lanarkshire coal reserves is a very serious matter for the heavy coal-consuming industries of the Clyde valley and for the ship-building and engineering works dependent on them; and the Committee was of the opinion that the question of long-distance carriage for assembling material essential to blast-furnaces and steel-works, is one calling for consideration.

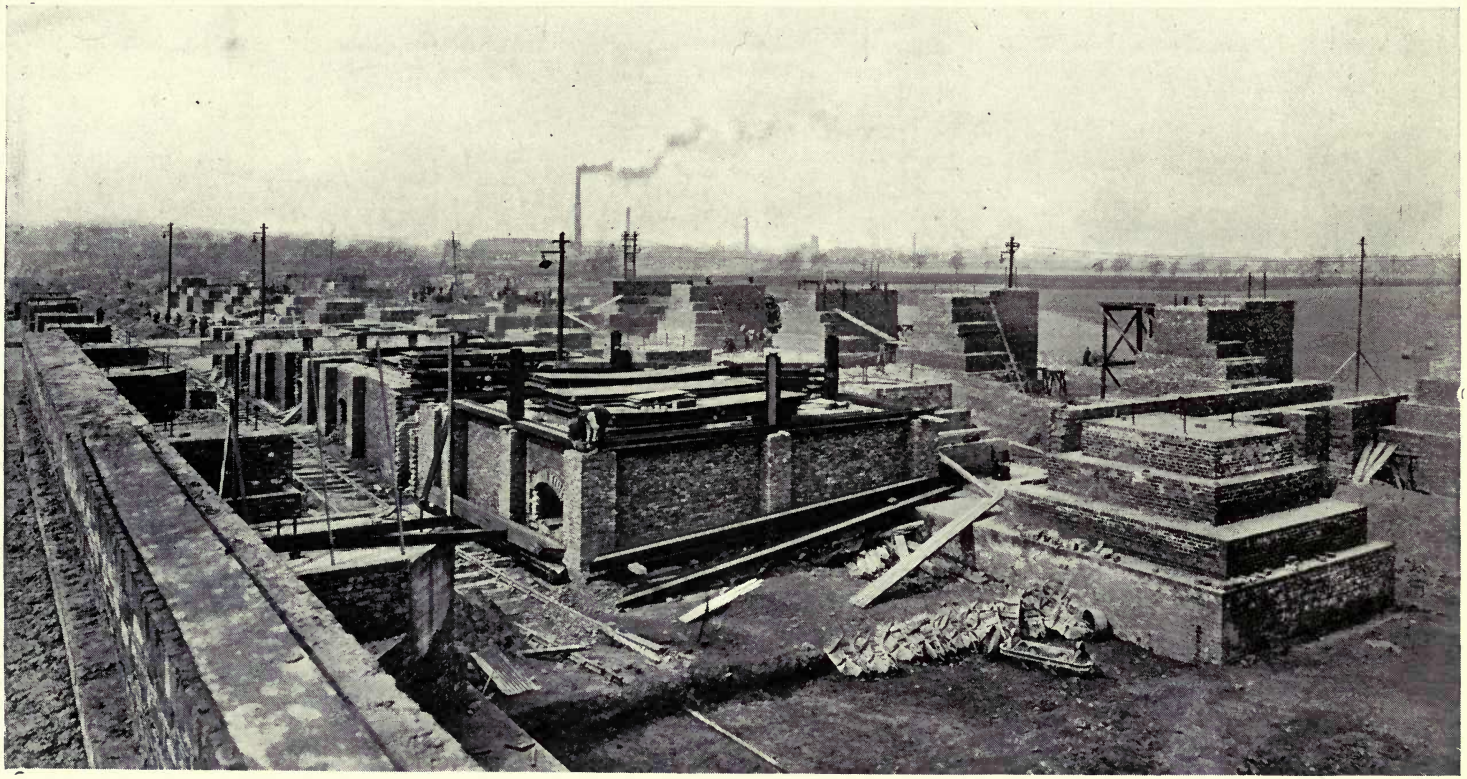


FIG. 14.—Extension to David Colville & Sons' steel-works at Clydebridge, near Glasgow, showing foundations for new melting shop. (May 1, 1917.)

CHAPTER XIV.

LIMESTONE.

In the autumn of 1916 it was found necessary to increase the supply of limestone in order to feed the additional blast-furnaces which, it was anticipated, would be put on to basic pig. With this end in view Mr. Merricks was commissioned by Sir John Hunter to inspect certain limestone quarries in the Weardale district of County Durham, in Yorkshire, in the Buxton district of Derbyshire, and in Cumberland and Lancashire. As a result, a number of these quarries were taken over by the Ministry and arrangements made to work them with prisoner labour. Camps for the accommodation of the prisoners were erected at Eastgate and Stanhope in Durham, at Stainton in Lancashire, at Rowrah in Cumberland, and at Peakdale and Ladmanlow in the Buxton district of Derbyshire. By the end of 1916 some 1,500 prisoners were at work. Mr. N. G. Hackney was appointed as the Ministry's representative in County Durham, with Mr. H. D. Keown as assistant, to take charge of the quarries, both of limestone and ganister, that were being worked by prisoners of war in that district. In May, 1917, Mr. Hackney also became responsible for the administration of the limestone quarries which were being worked in Derbyshire with prisoner labour by the Buxton Lime Firms Company, Limited; and in April, 1918, he took over the supervision of a dolomite quarry worked by prisoner labour in the Oswestry district of Shropshire. Mr. Lamotte was placed in charge of the Oswestry quarry and also of the Knitsley Fell ganister quarry in Weardale, which had been reopened by the Ministry to supply material for making

high-grade silica bricks. Altogether Mr. Hackney's organisation was responsible for 14 quarries worked by prisoner labour. Of these the following limestone quarries were in Weardale: Heights, Newfield, Newlandside and Rogerley, the prisoners being lodged in camps at Eastgate and Stanhope. The ganister quarries in Weardale were Knitsley Fell and Healyfield, the camps for these being at Harperley and Healyfield. In the Buxton district seven limestone quarries were worked with prisoner labour, namely, Grin, Harpur Hill, and Brierlow, with prisoners from Ladmanlow camp; Peakdale, Perseverance and Smalldale, with prisoners from Peakdale camp; and Alsop-en-le-dale, with prisoners from Ashbourne camp. In the Oswestry district of Shropshire the Whitehaven dolomite quarry was worked by prisoners from a camp at Parkhall.

Piece-rates were introduced both in Weardale and Buxton, and much to the advantage of production. In Weardale their introduction trebled the output per man; but the Ministry was prevented from reaping the full benefit of this increase by the opposition of the Cleveland Miners and Quarrymen's Association. At first the difficulty was overcome by placing the stone won by prisoner labour into reserve stock at the quarries; and by the end of December, 1917, approximately 65,000 tons had been accumulated on this account. But on further opposition from the Association it was found necessary to prohibit quarrying by prisoners altogether, and to utilise this labour solely for removing over-burden preparatory to the quarrying of the stone. In June, 1918, the question was finally settled by an agreement with the Cleveland Miners and Quarrymen's Association, under the terms of which prisoner labour was to be used for quarrying at the discretion of the Ministry, provided no British quarrymen suffered detriment or loss thereby.

In reporting on the use of prisoner labour Mr. Hackney remarks that the main obstacle to satisfactory results was the limitation of inducements to work. Work could not be compelled either by force, this being forbidden by the War Office regulations, or by a reduction of rations since a

minimum was prescribed. The difficulty was overcome, as already stated, by the introduction of piece rates. Here again, however, the best results could not be obtained since earnings beyond a fixed daily limit were prohibited. Further, there was no outlet for surplus earnings, the canteen supplies having been reduced, on account of the general shortage of food.

According to returns made to the Ministry, the present total consumption of limestone in blast-furnaces amounts to 4½ million tons per annum. Of this amount 41 per cent. is taken by furnaces in the Middlesbrough district, and is supplied from Weardale and East Yorkshire. Ironworks situated in the Midlands and in Staffordshire are the next biggest consumers, taking 23 per cent., mainly from Buxton and North Staffordshire. The remaining 36 per cent. is taken by furnaces on the West Coast (Cumberland and Lancashire), in Scotland, and in South Wales.

TABLE SHOWING THE CONSUMPTION AND SOURCE OF SUPPLY OF THE LIMESTONE USED IN BLAST-FURNACES.

District.	Percentage Ratio of Total Consumption.	Source of Supply.
East Coast	41 per cent.	Weardale and East Yorkshire.
Midlands (including Staffordshire)	23 „	Buxton and North Staffordshire.
West Coast	15 „	Local (Cumberland and Lancashire).
Scotland	12 „	Mainly imported from North Wales, Yorkshire and Buxton.
South Wales ...	9 „	South Wales.

CHAPTER XV.

REFRACTORY MATERIALS.

The chief refractory materials used in iron and steel making are :—

(1) FIRECLAY. (Firebricks, nozzles, stoppers, blast-furnace linings, etc., etc.)
(2) REFRACTORY SANDS.
(3) GANISTER AND SILICA-ROCK. (Silica-bricks and blocks.)
(4) MAGNESITE. (Magnesite-bricks and cement.)
(5) "BASIC MATERIAL." (Shrunk dolomite.)

Fireclay goods are used in all processes of iron and steel manufacture, refractory sands chiefly for moulding purposes in the foundries and acid steel-melting furnaces, silica-linings in acid steel-furnaces, whilst magnesite and "basic material" are used for the lining of basic steel-furnaces.

At the outbreak of war refractory sands were being imported in considerable quantities from the Continent; and home resources were either neglected or unknown. But recent investigations undertaken by Dr. Boswell,* of the Liverpool University, at the instance of the Steel Production Department, have demonstrated the entire suitability of the home materials for the purposes required and have made the United Kingdom independent in the future of foreign supplies.

With the exception of magnesite there were ample supplies of refractory materials in this country at the outbreak of war;

* P. G. H. Boswell: A Memoir on British Resources of Refractory Sands. published at the Instruction of the Ministry of Munitions of War by the Imperial College of Science and Technology and the University of Liverpool.

and the grinding and calcining plants, then at work, were capable of meeting the pre-war requirements of the steel-makers. This satisfactory position led manufacturers, who did not realise the increased demands that would eventually be made upon them, to encourage their younger and, in many cases, best employees to join the new armies. When first asked to increase their output they were able to respond by procuring and training additional labour; moreover, the majority of them had for a number of years been accustomed to carry large stocks; consequently they experienced no difficulty at first in meeting the increased demands. But early in 1916 it was realised that it would be necessary to take other measures to augment the output of refractories of all kinds; and for this purpose a Section of the Iron and Steel Department was created in July, 1916, under the administration of Mr. W. J. Jones. At first the Section dealt only with fireclay and ganister; but magnesite was taken over in November, 1916, and basic material in March, 1917.

Fireclay Materials.

In regard to these materials, the outlook in July, 1916, was not specially serious except in regard to blast-furnace linings. On enquiry it was found that the capacity of the works was approximately 120,000 tons of fireclay and bricks per month, equivalent to a monthly output of 40,000,000 bricks of 9 in. $\times$ $4\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in. dimensions. The output for the month of July, 1916, was 110,000 tons, and while the manufacturers were all well booked ahead, it did not appear that any great difficulty would be experienced in coping with orders, 90 per cent. of which were for war purposes. The monthly output continued at a steady average of 110,000 tons until April, 1917, in spite of the repeated withdrawal, for military service, of skilled and other labour from works in all parts of the country. Manufacturers generally were encouraged to maintain their output by a judicious dilution of their depleted staffs and by the installation of modern labour-saving machinery; and from May, 1917, onwards no difficulty was experienced in meeting

the increased demands put forward. By April of 1918 the output had reached an average of 135,000 tons per month, at which figure it has since been maintained.

Early in 1917 the demands for blast-furnace linings, both for repairs and for new construction, caused some anxiety, largely because consumers would insist on having the products of a limited number of firms. The problem was immediately taken in hand, and special returns were procured of the output of, and of the orders placed for, blast-furnace bricks and blocks. New requirements were carefully examined and a source of supply indicated. By the end of the year the arrears had been overtaken, since when all demands have been met without difficulty.

The requirements of the by-product coking industry gave some trouble. Prior to the outbreak of war, there were few firms in this country capable of supplying a brick suitable for the inside walls of coke-ovens; and the unfortunate experiences of the past had made coke-oven builders chary of using any but proved materials. This tended to restrict the home supply, and before the war the majority of the oven wall bricks in use were obtained from Germany, Belgium and France. The programme for the erection of a large number of by-product coking plants (see p. 98) created a demand which the English makers were quite incapable of meeting, and this for some time caused serious delay in the erection of new plants. Special returns of orders and of production were called for from makers of coke-oven bricks, and steps were taken to ensure that the best quality of bricks were restricted to the vital parts of the ovens, the use of equally suitable, but inferior, qualities being enforced in the remainder of the plants. A system of priority was devised for all new construction, and firms, possessing clays suitable for coke-oven wall bricks, were induced to undertake their manufacture.

By these means the total output of coke-oven bricks was increased from approximately 3,000 tons per month in August, 1916, to 6,700 tons in July, 1917. Since then the output maintained a steady average of 6,000 tons per month, and all demands were overtaken.

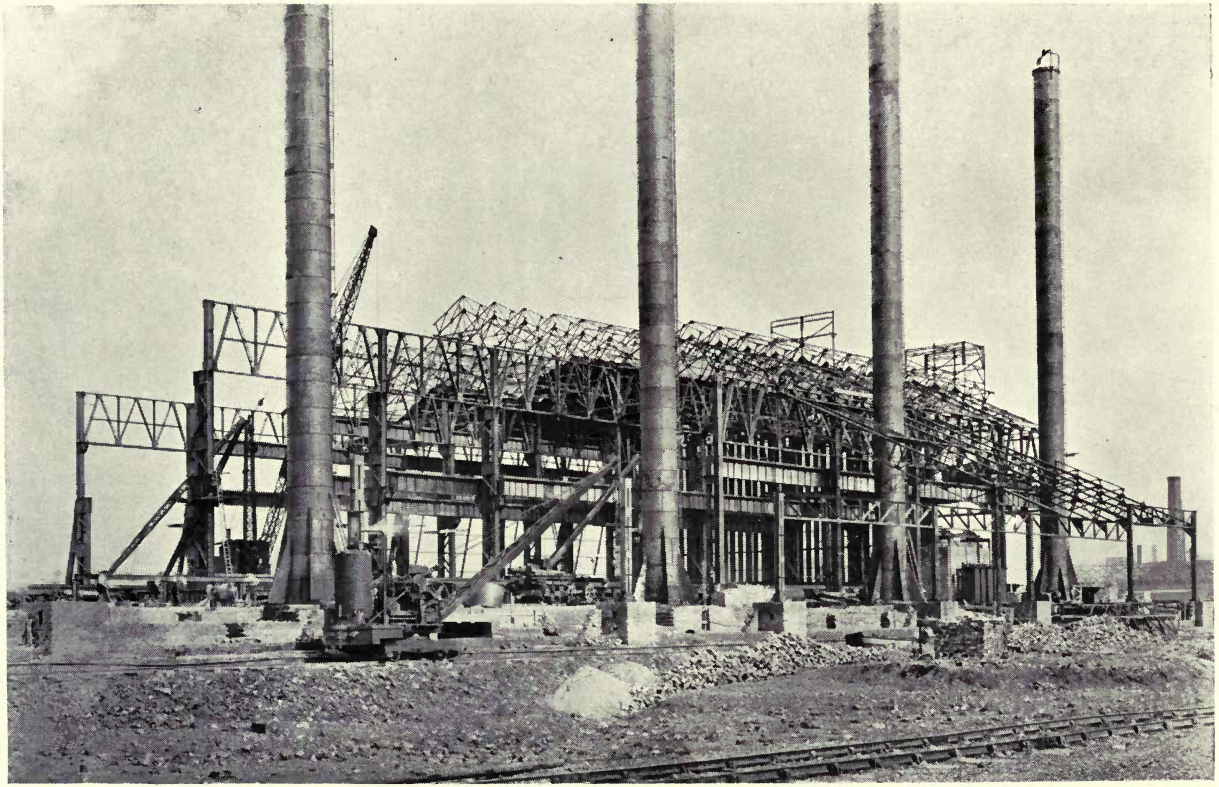


FIG. 15.—Extension to David Colville & Sons' steel-works at Clydebridge, near Glasgow. New melting shop. (September 4, 1917.)

GANISTER AND SILICA.

These refractories are in great need for steel-melting furnaces, as well as for non-ferrous furnaces, the combustion chambers of gas-retorts, etc.

The bulk of the goods are produced in South Yorkshire, Wales and Weardale, and to a smaller extent in Scotland. The South Wales manufacturers are fortunate in having ample supplies of high-grade silica-rock near at hand; while the South Yorkshire manufacturers have an excellent quality of ganister in the neighbourhood of their works. Owing, however, to a shortage of quarrymen the supply of Sheffield ganister was, early in the war, insufficient. It was sought to overcome this deficiency by grading and by mixing certain grades with a special stone quarried in North Yorkshire and North-west Durham, and as regards the quality of the material produced, the results were not unsatisfactory.

But the extensions to iron and steel works in progress in 1916 at length made the supply of high-grade silica goods totally inadequate, with consequent delay to construction; the maintenance of existing furnaces was even jeopardised, and this in some cases led to furnaces standing idle at a time when their output was most needed.

The total output of silica goods for July, 1916, with the works at their fullest capacity, was 7,966,000 "squares" of 9 in. $\times$ $4\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in., an output by no means equal to the requirements. To cope with the position it was decided to allocate the entire output to the steel-makers in proportion to their needs, and to restrict the use of first-grade bricks to steel-melting furnaces engaged upon essential munitions work, and to the vital parts of copper-smelting furnaces and of glass-furnaces. The requirements of other furnaces were met by the use of second-quality bricks, of which there was at this stage no acute shortage.

At a meeting of the leading makers, held at the Ministry on the 8th of November, 1916, further measures were concerted for increasing the output; and, in spite of the

continued shortage of labour, the output of silica- and ganister-bricks was by May, 1917, brought to a total of 10½ million bricks per month, at which figure it was maintained until the end of November, 1917. During this period, provision had to be made not only for home requirements, but also for the needs of the Allies and of the new steel-works in India and Australia; and shipments were also being made to Sweden to assist works engaged in the manufacture of special steels to the order of the Allies.

Magnesite.

Prior to the outbreak of war, the magnesite-brick industry was almost wholly in the hands of the Austrians, who not only possessed in their own country extensive deposits peculiarly suited for brick-making, but had devoted both skill and money to the perfecting of their products, with the result that they commanded practically the entire custom of the steel trade of this country. One, or two, at the most, of the British manufacturers had made small quantities of bricks from magnesite imported from Greece, but with little success.

On the outbreak of war energetic measures were at once required to make up for the loss of the Austrian material and to ensure an adequate supply to the manufacturers of basic steel. Arrangements were therefore entered into with a number of makers for the manufacture of magnesite-bricks at an agreed selling price, subject to the Ministry arranging for the tonnage necessary for the shipment of the raw material to this country, the price being regulated from time to time in accordance with the c.i.f. cost of raw magnesite.

In the latter part of 1916 a great increase in the demand for magnesite-bricks and cement was foreshadowed by the plans formulated by the Home Ore Supply Committee for an increased manufacture of basic iron. The total requirements for the year 1917, so far as could be foreseen on 31st December, 1916, amounted in terms of raw magnesite to 102,000 tons. This amount was far greater than the consumption of any previous year.

Owing to the uncertainty of the political position in Greece during the latter part of 1916, it became necessary not only to obtain from this source, without delay, as large a quantity as possible, but also to make arrangements for other sources of supply, in case this one should fail. Hitherto, practically the whole of the magnesite used in this country had been imported from the island of Eubœa, only a very limited tonnage being obtained from India.

Accordingly, contracts for the first six months of 1917 were made: (1) with the Anglo-Greek Magnesite Company, for the whole of the output from their mines in Eubœa; (2) with the Magnesite Syndicate, for the whole of the output from their mines in Madras; and (3) with Messrs. Allatini Brothers, of Salonica, for as much as they could supply from their mines in Yerakino. In all cases the Ministry had the option to continue the contract for the second half of 1917 on the same terms. Further, the local Director of the Anglo-Greek Company was instructed to buy up all he could from small mines in Eubœa not owned by his company.

The Admiralty, at the urgent request of the Ministry, arranged for armed forces to supervise the loading of vessels from the Anglo-Greek Company's mines, and to put in force such measures as might be deemed necessary to ensure that the Anglo-Greek Company's properties in the Isle of Eubœa should be worked solely in the interests of the Allies. The British Consul-General, and the Commander-in-Chief of the Army at Salonica were requested to afford assistance in regard to the Yerakino supplies. The Indian Government was also requested to co-operate in regard to the provision of labour, etc., to ensure as great an output as possible from the Salem mines of the Magnesite Syndicate.

In January, 1917, Mr. Merricks, Honorary Mining Engineer to the Ministry, inspected and reported, on behalf of the Department, upon the magnesite deposits of Castiglioncello, in Italy; but it was not found practicable to arrange for shipments to this country.

In view of a possible shortage, other measures were taken. An Order, dated the 9th of January, 1917, was made by the Minister of Munitions, prohibiting the use of magnesite and magnesite products for purposes not absolutely necessary, and for which substitutes could be found. Considerable economy in magnesite-bricks was effected by inducing steel-makers to adopt a modification of the form of lining of their basic steel-furnaces suggested by the Ministry. Further, in order to economise shipping space, the French and Italian authorities, whose estimated requirements for 1917 were equivalent to 27,000 tons of raw magnesite, were persuaded to put down brick-making plants, so as to be in a position to provide for their own needs.

To deal effectively with the situation, it was necessary for the Ministry to control both the import of magnesite to this country and its distribution after arrival; for this purpose, it was arranged that Messrs. Tennants (Lancs.), Limited, Liverpool, should act as distributing and collecting agents.

At the end of 1916, the stocks of magnesite in the country were equivalent to 52,508 tons of raw magnesite or, say, six months' supply. So successful were the measures taken by the Department that by the end of June, 1917, they had been increased to 72,291 tons.

The favourable development of the political situation in Greece had relieved the position to some extent, though the submarine activity of the enemy continued to be an adverse factor. By the end of 1917, however, 95,000 tons of raw magnesite had been safely landed in English ports; while the actual losses in transit incurred comprised seven cargoes, aggregating 23,744 tons. After providing for the requirements of all the industries concerned, the total stocks in the country on the 31st of December, 1917, aggregated 82,945 tons.

Basic Material and Shrunk Dolomite.

"Basic material," as it is popularly termed, is prepared by the calcining, at a suitable temperature, of magnesian lime-

stone, *i.e.*, dolomite, and is used for the preparation and the repair of the hearths of steel-furnaces using the basic process of steel-making. Forty to forty-five tons of the shrunk stone are needed to form the hearth of a 50- to 60-ton furnace, while for maintenance purposes practically 1 cwt. is required for every ton of steel produced. Although at the beginning of the war only four firms were engaged in calcining the stone for steel-works purposes, they were able to cope with the demands made upon them until the latter part of 1916. During that year the aggregate average monthly output totalled 10,175 tons ; and during the last two months of 1916 upwards of 11,000 tons of calcined dolomite was called for per month.

In February, 1916, when the Iron and Steel Department became responsible for the supply of " basic material," the increasing needs of the steel-makers and the proposals of the recently-constituted Home Ore Supply Committee for the increased production of basic steel, necessitated a very careful review of the situation. As a result it was found that new plant would be required to increase the monthly output of " basic material " to 17,500 tons per month, which amount, it was estimated, would be required by the end of July, 1917.

Early in March, 1917, the owners of the works then calcining dolomite were advised of the increased output required from their works, and arrangements were made for detailed plans and estimates of the necessary extensions to be submitted to the Ministry without delay. Further, Messrs. John Delaney, Limited, owners of a valuable dolomite quarry at Grassington, agreed to put down a plant to calcine dolomite at the rate of approximately 1,600 tons raw material per month. After careful consideration, the proposed extensions were sanctioned by the Munitions Works Board, before the end of March. The extensions to the dolomite-calcining plants were completed practically by Midsummer, 1917 ; but owing to labour troubles the requirements of the manufacturers of basic steel were considerably short of what had been anticipated, only 14,800 tons per month of " basic

material" being required in the last quarter of 1917 instead of the 17,500 tons per month for which provision had been made.

Early in 1918 fresh proposals for an extended use of home ores necessitated arrangements for an additional monthly output of 4,000 tons of "basic material," over and above the 17,500 tons already provided, and accordingly the Steetley Lime Company and the Yorkshire Basic Company arranged for further extensions to their plants to enable them to cope with the increased demand if required. The shortage of suitable labour throughout the country, however, delayed the completion of the extensions to steel-works to such a serious extent that the demand for "basic material" did not in any one month exceed 18,081 tons; but the position at the end of 1918 was in so far satisfactory that the calcining plants, as extended, were quite equal to coping with an additional supply of 4,000 tons per month, provided the additional labour required to man the extensions was forthcoming.

FIG. 16.—Extension to Bolckow, Vaughan & Co.'s steel-works at South Bank, near Middlesbrough. New open-hearth furnaces showing regenerator chamber and flues.

CHAPTER XVI.

FORGINGS, CASTINGS AND DROP-STAMPINGS.

A Section to control forgings and drop-stampings was started in September, 1915, under Sir Alfred Herbert, Deputy-Director-General of the Machine Tool Department.

Early in 1917 the demand for forgings for guns and for Admiralty work became so acute that it was felt that some re-organization was necessary. The Gun Consultative Committee were anxious to increase the output of guns, and Sir John Hunter was asked to form an organization in connection with the Iron and Steel Department to deal with this work. As a result the Department of Forgings, Castings and Drop-Stampings came into being, and Mr. D. M. Anderson was appointed Controller.

The first difficulty that Mr. Anderson had to contend with was the absence of suitable plant in this country, since prior to the war the trade was, to a large extent, in the hands of the Germans, and many forges in this country had ceased to operate on account of the severity of competition. The armament firms of this country were mostly employed on high-class Admiralty work, and a large number of heavy forgings came from Germany. Mr. Anderson immediately took steps to bring existing plant up to date, and to erect new plant of a more modern design so as to eliminate, as far as possible, manual labour, and to provide facilities for the necessary heat-treatment. The Department was responsible for all types of forgings; and, in order to secure an equitable distribution among the different departments requiring them, a committee was formed, on which were representatives of the Admiralty, Merchant Shipping, the Air Ministry, and the

departments dealing with railway materials, land and naval guns, etc. This committee advised as to the placing of the orders, and kept in touch with the manufacturers so as to ensure deliveries to date, as far as was possible in each case.

Later on the Department was extended to embrace steel castings, malleable iron and grey castings, and Commander A. E. Smithson was appointed Assistant-Controller for forgings, Mr. Ernest Wells, Assistant-Controller for castings, and Mr. A. Stubbs, Assistant-Controller for drop-stampings.

With regard to steel castings, it was found that the total capacity of the country was unable to meet the demand; consequently extensions to works and plant were made and improved methods of production established, especially in regard to repetition work, such as track-links for tanks (which were required at the rate of 75,000 per week), shells, agricultural machinery and miscellaneous repetition work. The supply of heavy castings for the stern-frames, rudders, etc., of battle-cruisers, destroyers and battleships, caused some trouble to the Department; but the necessary extensions to works were made, and ultimately the Department was able to meet all the calls made upon it. Large demands for steel castings came forward from Italy in connection with the merchant shipping programme of that country, and these were also met in due course.

With regard to malleable castings, the requirements of the army and the agricultural industry could not be met before existing works had been extended.

There was a big demand during the war for drop-stampings in connection with the production of aeroplanes, tanks, guns, shells, bombs, agricultural machinery, railway and other transport material. Before the war this was an industry employing about 4,000 hands. The increase of this number to over 12,000 during the war gave some difficulty, as it was necessary to train a large amount of unskilled labour. This was done partly by means of a Government instructional factory, partly by the goodwill of the stamping-firms throughout the country. The great majority of drop-stampings are made of high-class alloy steel, and require a thorough

knowledge of heat-treatment. Notwithstanding the difficulties that had to be contended with, the Department was able to meet the whole of the demands of the increased programmes.

In order to co-ordinate supply and production, a Committee of representatives of the State departments concerned, together with representatives of the trade, was formed.

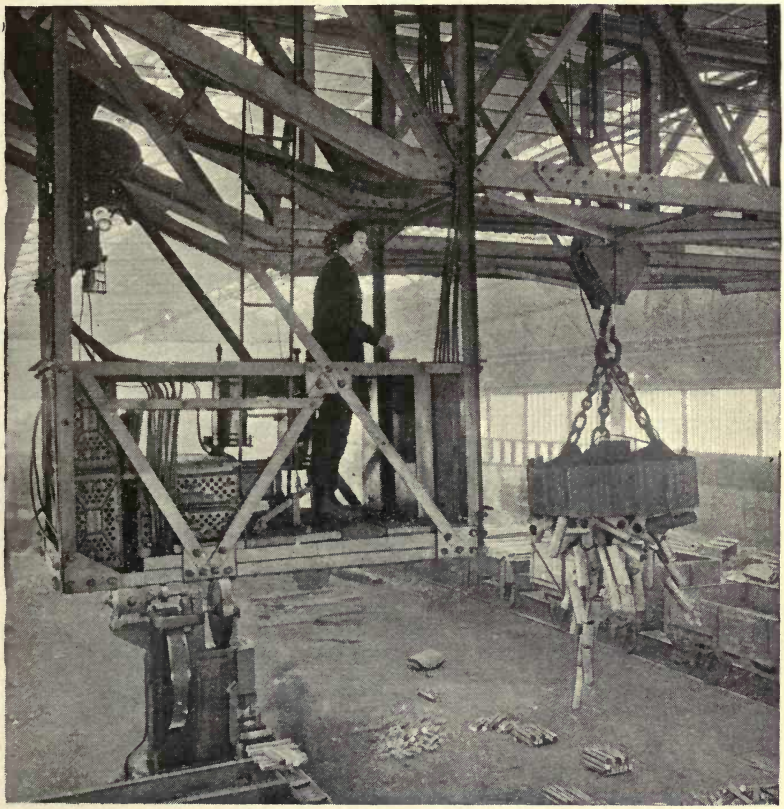


FIG. 17.—Electro-magnet in use at Messrs. Dorman, Long & Co.'s works at Middlesbrough.

The success of the Department as a whole was due to the fact that its technical staff was composed of men conversant with the respective trades, and able to tackle successfully the difficult problems as they arose. Much assistance was rendered by the forge-masters, the steel, iron and malleable iron-founders and the drop-forgers, who worked together

with one end in view, namely, to increase the production of all the materials required. The new plant erected during the war will enable the firms to take on post-war work, and they should now be in a position to compete successfully with foreign countries.

CHAPTER XVII.

SUMMARY OF STATISTICS RELATIVE TO THE PRODUCTION OF RAW MATERIALS, PIG-IRON AND STEEL DURING THE WAR PERIOD.

In this chapter comparative statistics are given for the years 1913 to 1918 inclusive. They are grouped under: A, Semi-manufactured Materials; B, Raw Materials.

The semi-manufactured materials for which statistics are given comprise pig-iron and ingot-steel.

The raw materials for which statistics are given are:—

1. Iron ore: imports, production and ore available for consumption in British blast-furnaces.
2. Manganese ore: imports and production.
3. Coke: home consumption, exports and production.
4. Limestone: deliveries.
5. Refractory materials: imports and exports, production and consumption of magnesite, dolomite, magnesite-bricks, silica-bricks and fire-bricks.

A.—Semi-manufactured Materials.

1. *Steel.*

The following table gives the production of Steel Ingots and Castings in the United Kingdom since 1913.

The figures for the years 1913-1915 (inclusive) are taken from the Iron and Steel and Allied Trades Federation Statistical Report for 1917; those for the years 1916, 1917 and 1918 are compiled from returns made to the Ministry of Munitions.

PRODUCTION OF STEEL.

Year.	Acid.	Basic.	Total.
	Tons.	Tons.	Tons.
1913	4,860,154	2,803,722	7,663,876
1914	4,477,920	3,357,193	7,835,113
1915	4,912,160	3,637,855	8,550,015
1916	5,421,583	3,570,146	8,991,729
1917	5,673,150	4,043,394	9,716,544
1918	4,992,106	4,547,333	9,539,439

It will be seen that there was a considerable increase in total production. Since the beginning of 1917 the output of basic steel increased in conformity with that of basic pig-iron, while the output of acid steel fell off. This resulted from the increased use of home iron-ores. The rise in the output of basic steel from the first quarter of 1917, when the Home Ore Supply Committee was formed, was more than sufficient to off-set the fall in the output of acid steel. During the first half of 1918 the total production was at the rate of close on 10,000,000 tons per annum; but it fell off during the latter half of the year, owing to the recruitment of men from iron and steel works to supply the urgent need of the armies in the field. Of the total output of steel in 1916, 39·7 per cent. was basic; whereas in 1918 the proportion was 48 per cent.

2. *Pig-iron.*

The production of pig-iron in the United Kingdom since 1913 was as follows :—

PRODUCTION OF PIG-IRON.

Year.	Hematite.	Basic.	Forge and Foundry.	Alloys.	Total Pig-iron.
	Tons.	Tons.	Tons.	Tons.	Tons.
1913	3,604,823	2,529,800	3,801,547	324,145	10,260,315
1914	3,225,403	2,002,500	3,369,516	326,354	8,923,773
1915	3,564,276	2,272,684	2,701,215	255,484	8,793,659
1916	4,042,014	2,290,549	2,423,575	291,845	9,047,983
1917	3,921,927	2,722,791	2,378,870	298,190	9,321,778
1918	3,556,748	2,986,827	2,301,802	240,975	9,086,352

The figures for the years 1913 and 1916 (inclusive) are taken from the Iron and Steel and Allied Trades Federation Statistical Report for 1917 ; those for the years 1917 and 1918 are compiled from returns made to the Ministry of Munitions. It will be seen that there has been a steady increase in the total output of pig-iron since the beginning of 1916 up to the beginning of 1918, against a decrease in the output of hematite pig-iron since March, 1917. The increase is due to an augmented production of basic pig-iron, since the output of foundry and forge makes remained practically stationary.

B.—Raw Materials.

1. *Iron-ore.*

The imports of iron-ore into the United Kingdom since 1913, according to H.M. Customs returns, were as follows :—

IMPORTS OF IRON-ORE.

Year.	Manganiferous Iron Ores.	Other Iron Ores.	Total Imports.
	Tons.	Tons.	Tons.
1913	211,644	7,230,600	7,442,244
1914	165,493	5,539,255	5,704,748
1915	138,968	6,058,187	6,197,155
1916	81,992	6,823,944	6,905,936
1917	135,061	6,054,594	6,189,655
1918	123,606	6,442,254	6,565,860

Of these imports the bulk came from Spain and the Mediterranean and from Scandinavia. The proportions in which they were consigned from these countries is expressed in the following table :—

ORIGIN OF IMPORTED IRON-ORES.

	1913.	1914.	1915.	1916.	1917.	1918.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Spain and the Mediterranean	80·5	83	86	84	94	91
Scandinavia ...	11·5	11	12	15	5	8
Sundry... ...	8·0	6	2	1	1	1

Speaking generally, the imports from Scandinavia consist of magnetic ore, rich in phosphorus (1 per cent. and over), and in such ores the phosphorus is a valuable asset in connection with the production of basic slag. On the other hand the ores from Spain and the Mediterranean are as a rule hematites low in phosphorus. Some of the Spanish ore, however, falls into the phosphoric class. It is impossible to divide the imports sharply into the two classes of "phosphoric" and "non-phosphoric," since there are ores on the border line which, according to the needs of the ironmasters, are used sometimes for making hematite pig and sometimes for basic pig.

Of the manganiferous iron-ores—*i.e.*, ores containing less than 30 per cent. of manganese—95 per cent. come from the Mediterranean. They are imported for use in making spiegeleisen, and for mixing with other ores to produce special pig-irons.

The production of home iron-ores since 1913 has been as follows :—

PRODUCTION OF HOME IRON-ORES.

Year.	Hematite (Cumb. & Lancs.).	Phosphoric Iron-ores.	Total Outputs.
	Tons.	Tons.	Tons.
1913	1,767,088	14,230,240	15,997,328
1914	1,630,682	13,236,900	14,867,582
1915	1,656,494	12,578,518	14,235,012
1916	1,608,353	11,886,305	13,494,658
1917	1,586,429	13,441,473	15,027,902
1918	1,549,962	13,494,411	15,044,373

The figures for the years 1918 and 1917 are compiled from returns made direct to the Mining Section of the Iron and Steel Production Department of the Ministry by the mine and quarry owners. Those for the previous years are from Home Office returns.

The production of home iron-ore in 1917 shows an advance on the previous year of over $1\frac{1}{2}$ million tons. The increase was in the production of phosphoric ore, since the output of hematite decreased slightly in the same period.

The bulk of the increase was in the Midlands and was due to the more extended application of steam-shovels, transporters and other mechanical devices for uncovering, breaking and loading the ironstone. In the early part of the year 1918, 13,000 tons of ironstone from the North Lincolnshire, Northamptonshire and Oxfordshire districts, were being sent weekly to the Cleveland district and 5,000 tons to South Wales, special measures having been taken by the Transport Section of the Department to meet the heavy strain put thereby on the railway services.

During the first half of 1918 the increase was continued and, if maintained, would have brought 1918 on a level with the record year (1913). Unfortunately, the shortage in labour caused by the Army requirements and the sickness caused by two epidemics of influenza led to a serious falling off in output during the second half of the year, and the total production for the year was no better than that of 1917.

Iron-ore available for Blast-furnaces.—The following table gives for the years 1913–1914 the iron-ore available for consumption in British furnaces, *i.e.*, the total quantity of iron-ore, exclusive of scale, tap, cinder, etc. It is got by adding to the home production the imports and the production of " purple ore " (which is the residue of cupreous iron pyrites, calculated at 66·6 per cent. of the raw cupreous pyrites imported) and deducting the exports. The second table gives the ratio of imports, " purple ore " and home production to consumption.

ORE AVAILABLE FOR BRITISH FURNACES.

Year.	Imports.	" Purple Ore."	Home Production.	Exports.	Ore available for British Furnaces.
	Tons.	Tons.	Tons.	Tons.	Tons.
1913 ...	7,442,244	521,140	15,997,328	6,378	23,954,334
1914 ...	5,704,748	535,432	14,867,582	13,529	21,094,233
1915 ...	6,197,155	602,312	14,235,012	1,669	21,032,810
1916 ...	6,933,767	633,330	13,494,658	1,100	21,060,655
1917 ...	6,189,655	569,494	15,027,902	667	21,787,051
1918 ...	6,565,860	557,802	15,044,373	160	22,167,875

In the above table the figures for the imports and exports are from Board of Trade returns; those for the home production, up to the year 1916 (inclusive), are from Home Office returns, and since that date from returns made to the Ministry of Munitions. The figures for "purple ore" are calculated from Board of Trade returns for imported raw cupreous pyrites. It will be seen from this table that the iron-ore available for consumption during 1918 was at a higher rate than any previous year during the war.

TONNAGE PERCENTAGES.

Year.	Imports.	"Purple Ore."	Home Production.	Ore available for Consumption.
	Per cent.	Per cent.	Per cent.	Per cent.
1913 ...	31·0	2·2	66·8	100
1914 ...	27·0	2·5	70·5	100
1915 ...	29·5	2·8	67·7	100
1916 ...	32·8	3·0	64·2	100
1917 ...	28·4	2·6	69·0	100
1918 ...	29·6	2·5	67·9	100

This table gives the proportion of the ore available for consumption attributable to each source. On account of the disparity of the iron-content of these different ores, the importance of the home sources as regards iron production is less than it would appear to be. Thus the ratio of imports, "purple ore" and home ores, worked out on an average metallic iron content of 50 per cent. for imported ores, 63 per cent. for "purple ore," and 30 per cent. for home ores, is for 1918 as follows:—

Imported ores	40.3
Purple ore	4.4
Home ores	55.3
	100.0

In other words, the iron yield of the home ores was in 1918 not much more than half the total yield from all ores. In this calculation no account is taken of the iron recovered

from scrap, cinder, etc., which is, of course, a very important factor in the iron-smelting of this country.

2. *Manganese Ore.*

Manganese ores, properly so-called, contain not less than 45 per cent. of manganese; but inferior grades, containing down to 25 per cent. manganese, have been mined in this country during the war.

The imports and home production of manganese ores since 1913 have been as follows:—

IMPORTS AND PRODUCTION OF MANGANESE ORES.

Year.	Imports.	Production.	Total (representing Consumption).
	Tons.	Tons.	Tons.
1913	601,177	5,393	606,570
1914	479,435	3,437	482,872
1915	372,724	4,640	377,364
1916	440,659	5,140	445,799
1917	331,264	13,094	344,358
1918	365,606	14,942	380,548

The figures for the imports are from Board of Trade returns; those for the home production to the year 1916 (inclusive) from Home Office returns, and since that date from returns made to the Ministry of Munitions.

Before the war, imports came mainly from India, Russia and Brazil in the following proportions (1914): India, 47 per cent.; Russia, 37 per cent.; Brazil, 10 per cent.; and other countries, 6 per cent. Since 1914 they have been drawn almost entirely from India. In 1917 shipments were commenced from Sekondi on the West Coast of Africa. Amounting to only one per cent. of the total importation in that year they were four per cent. in the first half of 1918, and by the month of August, had grown to about 15 per cent.

The home production in 1917 showed an increase of 155 per cent. on that of the previous year, and in 1918 there was a further increase of 25 per cent. on the 1917 figures. This augmentation of home production was brought about by the

Ministry in order to relieve, as far as possible, the stringency in importation caused by the want of ship tonnage. The manganese mines of the United Kingdom are confined to North Wales (Merionethshire and Carnarvonshire), where the ores consist of mixed silicate and carbonate, in part changed to the richer oxides near the surface.

Of the 1917 consumption, 85 per cent. went to the makers of ferro-manganese, the remaining 15 per cent. being used in connection with basic pig manufacture.

3. *Coke.*

The production, home consumption and export of metallurgical coke since 1914 has been as follows :—

Year.	Home Consumption.	Export.	Production.
	Tons.	Tons.	Tons.
1914	—	—	11,050,256
1915	11,515,312	621,533	12,136,845
1916	12,291,992	1,130,203	13,422,195
1917	12,922,896	878,711	13,801,607
1918	12,666,775	634,773	13,301,548

The high figures for export are due to the war demands of the Allies, a large quantity of coke having been exported to France and Italy for foundry purposes, which, before the war was furnished by Belgium and Germany. France had to draw still more largely on this country in 1916, owing to the loss of the coke-ovens in the Pas de Calais coalfield. Since the beginning of 1917, however, the French demands have been reduced owing to her increased production.

The rise in home consumption is accounted for by the greater number of blast-furnaces put into operation in the United Kingdom. In 1917 blast-furnace requirements amounted to 79 per cent. of the output; 6 per cent. was exported, the remaining 15 per cent. being used for miscellaneous purposes, such as foundry work, and in the manufacture of high-speed steel.

Of the total production of metallurgical coke, 80 per cent. was furnished by by-product ovens, together with benzol,

sulphate of ammonia and crude tar. The coal required for the manufacture of metallurgical coke was 22,000,000 tons per annum. Under the programme for increasing the output of steel to 12,000,000 tons per annum, large additional quantities will be required. The additional by-product ovens, which it is proposed under this programme to provide, will ultimately place the total production of metallurgical coke in this country on the basis of $16\frac{1}{2}$ million tons per annum. The use of $8\frac{1}{4}$ million tons more coal, representing the work of 33,000 coal miners, will be entailed.

4. *Limestone.*

Previous to the last quarter of 1917, the Ministry kept no record of the deliveries to, and the stocks kept at, blast-furnaces.

The returns for 1918 show a consumption in blast-furnaces of $4\frac{1}{3}$ million tons per annum, thus :—

	Tons.
Deliveries to works	4,364,734
Added to stocks at works	43,270
Consumption in blast-furnaces ...	4,321,464

5. *Refractory Materials.*

The raw refractory materials used in steel-making consist of magnesite, dolomite, ganister and fire-clay. The first named is imported from abroad (Greece or India), while the others are produced in this country.

Magnesite is used for the manufacture of magnesite bricks for the lining of basic steel furnaces. Dolomite in the calcined ("shrunk") state is termed "basic material," and before being used to form the hearths of basic steel-furnaces is ground and mixed with dehydrated tar. Ganister goes to make the silica-bricks required for the construction of acid steel-furnaces and converters, while fire-clay is used for making fire-bricks.

The imports of magnesite for the years 1917 and 1918 are as follows :—

	1917. Tons.	1918. Tons.
Raw magnesite	65,369	39,930
Caustic calcined magnesite...	4,570	1,424
Hard burnt magnesite ...	4,454	Nil
Dead burnt magnesite ...	6,414	447
Total equivalent raw ...	95,045	43,672

According to returns made to the Ministry of Munitions the production of raw dolomite for the manufacture of basic material for the years 1917 and 1918 was as follows :—

	1917. Tons.	1918. Tons.
Raw dolomite (used raw) ...	68,027	39,847
Shrunk dolomite	152,880	184,655
Total equivalent raw ...	373,787	409,157

The production, export and home consumption of magnesite bricks were as follows :—

	1916.	1917.	1918.
	Bricks.	Bricks.	Bricks.
Production	5,307,270	5,813,924	3,981,342
Home consumption ...	—	4,867,302	3,668,791
Export	—	946,622	312,551

The production of silica-bricks for the last three years was as follows :—

1916 (estimated) ...	97,717,000	Bricks.
1917	122,465,000	do.
1918	100,400,000	do.

The production of fire-bricks and coke-oven bricks for the last three years was as follows :—

	1916 (Estimated).	1917.	1918.
	Tons.	Tons.	Tons.
Fire-bricks (certain works only)	1,306,890	1,448,162	1,508,000
Coke-oven bricks ...	43,896	71,571	64,416

APPENDIX I.

Average Analyses of British Iron-Ores and Ironstones Produced in 1917–18. Prepared by F. H. Hatch for the Iron and Steel Production Department.

The figures given in the following tables of analyses represent the majority of the iron-ores and ironstones of the United Kingdom, and have been obtained by systematising and averaging a large number of analyses furnished to the Ministry of Munitions through the courtesy of the ironmasters. In every case the sampling was done at the iron-works where the ores are smelted.

West Coast Hematite Ores.

The figures given in the tables represent the results of averaging analyses of hematite supplied by the following companies using this ore :—

Barrow Hematite Steel Co., Ltd.
Carnforth Hematite Iron Co., Ltd.
Distington Hematite Iron Co., Ltd.
Millom & Askam Hematite Iron Co., Ltd.
North Lonsdale Iron and Steel Co., Ltd.
Whitehaven Hematite Iron and Steel Co., Ltd.
Workington Iron and Steel Co., Ltd.

The number of mines represented is 27, and the number of analyses averaged is over 1,500.

Jurassic Ironstones of Cleveland, North Lincolnshire, and the Midlands.

Analyses of these ironstones were supplied by the following companies using them in their furnaces :—

Alfred Hickman, Ltd.
Appleby Iron Co., Ltd.
Baldwins, Ltd.
Bell Bros., Ltd. (Clarence Ironworks).
Bestwood Coal and Iron Co., Ltd.
Bolckow, Vaughan & Co., Ltd.
Brymbo Steel Co., Ltd.
Cochrane & Co., Ltd.
Cargo Fleet Iron Co., Ltd.
Claycross Co., Ltd.
Crawshay Bros., Ltd. (Cyfarthfa Works).
Ebbw Vale Steel, Iron and Coal Co., Ltd.
Frodingham Iron and Steel Co., Ltd.
Guest, Keen & Nettlefolds, Ltd. (Cwm Bran Works).
Holwell Iron Co., Ltd.
James Oakes & Co. (Alfreton Works).
Kettering Iron and Coal Co., Ltd.
J. Lysaght, Ltd.
Midland Coal, Coke and Iron Co., Ltd.
North Eastern Steel Co., Ltd.
North Lincolnshire Iron Co., Ltd.
Palmers Shipbuilding and Iron Co., Ltd.
Parkgate Iron and Steel Co., Ltd.
Partington Iron and Steel Co., Ltd.
Pease & Partners, Ltd.
Shelton Iron, Steel and Coal Co., Ltd.
Skinningrove Iron Co., Ltd.
Sir B. Samuelson & Co., Ltd.
Stafford Coal and Iron Co., Ltd.
Staveley Coal and Iron Co., Ltd.
Walter Scott, Ltd.
Willingsworth Iron Co., Ltd.

The mines and quarries of 60 companies are represented.

N.B.—The upper line of figures for the ore of each mine or quarry in the tables gives the analysis of material dried at 212° Fahrenheit; the lower line, the analysis of material in its natural condition, as received at the ironworks.

1. West Coast Ores (Hematite). 1917–18.

Mine.	District.	——	Iron.	Silica.	Lime.	Phosphorus.	Moisture.
CUMBERLAND—							
Beckermet (Winscales)	Egremont ...	Dry ...	51·24	16·72	1·81	—	
		Nat. ...	49·26	16·07	1·74	—	3·88
Berrier	Cleator Moor ...	Dry ...	—	—	—	—	
		Nat. ...	55·32	8·93	—	—	—
Bigrigg (Sir John Walsh)	Cleator	Dry ...	48·55	16·90	3·75	—	
		Nat. ...	46·81	16·30	3·62	—	3·60
Cleator (No. 24 Pit)	Do. ...	Dry ...	50·27	17·77	—	·007	
		Nat. ...	48·24	17·06	—	·007	4·34
Cleator (Margaret Pit)	Frizington ...	Dry ...	47·05	18·43	—	·013	
		Nat. ...	45·21	17·42	—	·013	5·43
Crossfield	Cleator Moor ...	Dry ...	—	—	—	—	
		Nat. ...	48·67	13·39	—	—	—
Dalzell's Moor Row	Cleator	Dry ...	—	—	—	—	
		Nat. ...	56·90	7·10	—	·007	—
Highhouse	Frizington ...	Dry ...	—	—	—	—	
		Nat. ...	45·48	14·61	—	—	—
Hodbarrow	Millom	Dry ...	59·32	6·25	—	·005	
		Nat. ...	55·72	5·87	—	·005	6·07
Jacktrees	Cleator Moor ...	Dry ...	—	—	—	—	
		Nat. ...	40·71	21·43	—	—	—

1. West Coast Ores (Hematite). 1917–18—*continued.*

Mine.	District.	——	Iron.	Silica.	Lime.	Phosphorus.	Moisture.
CUMBERLAND—*continued.*							
Lamplugh	Lamplugh ...	Dry ...	50·71	13·01	4·58	—	
		Nat. ...	48·31	12·48	4·36	—	4·74
Leconfield's Bigrigg	Cleator Moor ...	Dry ...	—	—	—	—	
		Nat. ...	53·76	9·97	—	—	—
Lindow's Longlands	Cleator	Dry ...	—	—	—	—	
		Nat. ...	53·47	16·02	—	—	—
Lonsdale	Frizington ...	Dry ...	45·43	14·65	—	·009	
		Nat. ...	43·02	13·88	—	·009	5·31
Mowbray	Do. ...	Dry ...	40·44	22·01	4·99	—	
		Nat. ...	38·32	20·94	4·73	—	5·25
Parkhouse	Cleator	Dry ...	47·46	11·19	6·13	·007	
		Nat. ...	44·47	10·49	5·75	·007	6·31
Parkside (Crossgill)	Frizington ...	Dry ...	—	—	—	—	
		Nat. ...	42·00	—	—	—	
Postlethwaite's Moor Row (No. 6 Pit)	Cleator	Dry ...	—	—	—	—	
		Nat. ...	52·24	12·8	—	—	—
Stirling's Montreal	Frizington ...	Dry ...	53·60	13·00	—	·009	
		Nat. ...	50·92	12·36	—	·009	5·00
Townhead	Egremont ...	Dry ...	—	—	—	—	
		Nat ...	52·40	11·15	—	—	

Ullbank (No. 1 Pit)	Do. ...	Dry ...	—	—	—	—	—
		Nat. ...	37·16	18·00	6·45	·013	5·60
Ullcoats	Do. ...	Dry ...	51·54	16·33	1·82	·008	
		Nat. ...	48·69	15·57	1·73	·008	4·63
Woodend	Cleator	Dry ...	47·10	17·43	3·75	·015	
		Nat. ...	44·69	16·54	3·56	·014	5·13
Wyndham (Helder and No. 4 Pits)	Egremont ...	Dry ...	50·58	17·31	—	·008	
		Nat. ...	47·50	16·27	—	·008	6·09
LANCASHIRE—							
Kennedy's Nigel	Askam	Dry ...	57·30	14·40	—	·015	
		Nat. ...	54·80	13·77	—	·014	4·38
Kennedy's Roanhead	Do.	Dry ...	51·67	22·90	—	·018	
		Nat. ...	48·25	21·38	—	·017	6·62
Newton (Woodbine) Pit	Dalton	Dry ...	56·77	13·34	—	·014	
		Nat. ...	52·93	12·44	—	·013	6·77
North Lonsdale	Ulverston ...	Dry ...	—	—	—	—	
		Nat. ...	49·50	9·22	—	—	—
Park (Burlington Mines)	Dalton	Dry ...	52·66	18·49	—	·016	
		Nat. ...	48·16	16·91	—	·015	8·35
Pennington	Ulverston ...	Dry ...	47·10	13·09	—	·007	
		Nat. ...	43·53	12·11	—	·007	7·58
Yarlside	Dalton	Dry ...	50·40	16·93	—	·024	
		Nat. ...	45·83	15·40	—	·022	9·08

2. Cleveland Ironstones (Middle Lias). 1917.

Mine.	Owner.	—	Iron.	Manganese.	Silica.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.	Loss on Ignition (Combined H_2O and CO_2).	Moisture.	Oxygen.	Total.
Belmont ...	Bolckow, Vaughan & Co.	Dry	27·90	0·32	12·43	10·05	5·25	3·61	0·06	0·46	30·71		8·71	99·50
		Nat.	26·70	0·31	11·89	9·61	5·02	3·45	0·06	0·44	29·38	4·31	8·33	99·50
Boulby ...	Skinningrove Iron Co., Ltd.	Dry	28·54	0·27	15·43	9·82	6·29	3·28	0·02	0·45	25·16		10·19	99·45
		Nat.	25·97	0·25	14·04	8·94	5·72	2·98	0·02	0·41	22·90	9·00	9·22	99·45
Brotton ...	Morrison and Co. ...	Dry	30·95	0·59	11·95	11·25	5·00	3·81	0·32	0·49	25·53		10·26	100·15
		Nat.	27·67	0·53	10·64	10·02	4·45	3·39	0·29	0·44	22·72	11·00	9·00	100·15
Eston ...	Bolckow, Vaughan & Co.	Dry	33·35	0·49	8·99	10·38	5·15	3·63	0·11	0·65	26·53		10·90	100·18
		Nat.	30·37	0·45	8·20	9·45	4·69	3·31	0·10	0·59	24·16	8·93	9·93	100·18
Grinkle Park	Grinkle Park Mining Co.	Dry	26·54	0·24	15·00	12·73	5·00	2·80	0·27	0·53	26·89		10·00	100·00
		Nat.	24·60	0·22	13·90	11·80	4·70	2·60	0·25	0·49	24·92	7·30	9·22	100·00
Kilton ...	Dorman, Long & Co., Ltd.	Dry	29·09	0·29	15·40	10·82	4·65	4·23	0·15	0·45	25·01		9·25	99·34
		Nat.	27·63	0·27	14·63	10·28	4·42	4·02	0·14	0·43	23·74	5·00	8·78	99·34
Lingdale ...	Pease & Partners ...	Dry	27·96	0·31	15·70	12·29	4·90	3·74	0·44	0·48	24·69		9·19	99·70
		Nat.	26·12	0·29	14·67	11·58	4·58	3·49	0·41	0·45	23·07	6·55	8·49	99·70
Loftus ...	Do. ...	Dry	28·75	0·66	15·00	9·87	5·54	4·01	0·15	0·49	24·94		10·29	99·70
		Nat.	26·39	0·61	13·84	9·06	5·09	3·69	0·14	0·45	22·90	8·20	9·33	99·70

Longacres ...	Bolckow, Vaughan & Co.	Dry	32·12	0·33	10·00	9·53	5·64	3·77	0·24	0·44	26·82		10·79	99·68
		Nat.	28·91	0·30	9·04	8·58	5·08	3·39	0·22	0·40	24·14	10·00	9·62	99·68
Lumpsey ...	Bell Bros., Ltd. ...	Dry	29·33	0·40	14·30	12·28	5·39	3·97	0·26	0·50	24·20		9·37	100·00
		Nat.	27·85	0·38	13·58	11·65	5·11	3·76	0·25	0·47	22·95	5·00	8·80	100·00
North Skelton	Bolckow, Vaughan & Co.	Dry	30·99	0·50	12·39	10·83	4·70	3·80	0·21	0·50	25·97		9·98	99·87
		Nat.	29·36	0·48	11·84	10·27	4·46	3·60	0·20	0·47	24·60	5·24	9·35	99·87
Park Pit ...	Bell Bros., Ltd. ...	Dry	31·99	0·49	9·98	9·05	5·32	4·55	0·63	0·52	26·96		10·20	99·69
		Nat.	29·49	0·45	9·20	8·34	4·91	4·20	0·58	0·48	24·85	7·80	9·39	99·69
Roseberry ...	Tees Furnace Co. ...	Dry	27·69	0·48	13·69	12·16	6·60	3·45	0·84	0·53	24·76		9·16	99·36
		Nat.	25·43	0·44	12·57	11·17	6·07	3·17	0·77	0·49	22·75	8·10	8·40	99·36
Skelton ...	Bell Bros., Ltd. ...	Dry	31·51	0·43	11·22	9·01	5·70	4·42	0·55	0·54	26·05		10·17	99·60
		Nat.	29·42	0·40	10·48	8·46	5·32	4·13	0·51	0·50	24·33	6·60	9·45	99·60
South Skelton	Bolckow, Vaughan & Co.	Dry	34·13	0·42	9·22	8·99	4·71	4·13	0·01	0·41	27·19		10·75	99·96
		Nat.	33·30	0·41	9·00	8·75	4·60	4·00	0·01	0·40	26·53	2·44	10·52	99·96
Spawood ...	Sir B. Samuelson & Co., Ltd	Dry	28·73	0·42	13·29	12·76	5·85	3·52	0·32	0·50	25·55		9·03	99·97
		Nat.	27·00	0·39	12·49	11·99	5·50	3·31	0·30	0·47	24·00	6·00	8·52	99·97
Stanghow ...	Cochrane & Co. ...	Dry	27·91	0·49	14·96	12·30	5·60	3·67	0·44	0·51	24·75		9·13	99·76
		Nat.	26·10	0·46	13·94	11·46	5·22	3·42	0·42	0·48	23·05	6·80	8·41	99·76
Upleatham ...	Pease and Partners ...	Dry	32·37	0·39	10·99	11·32	4·39	3·59	0·63	0·53	24·34		10·75	99·30
		Nat.	29·74	0·36	10·10	10·40	4·04	3·30	0·58	0·49	22·36	8·14	9·79	99·30

3. North Lincolnshire Ironstones (Lower Lias). 1917.

Quarry and Owner.	—	Iron.	Manganese.	Silica.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.	Moisture.	Difference (Combined H_2O, CO_2).	Total.
Frodingham Iron and Steel Co. ...	Dry ...	25·56	0·99	12·32	6·79	19·07	1·62	0·08	0·32		33·25	100·00
	Nat....	22·65	0·88	10·92	6·02	16·90	1·44	0·07	0·29	11·40	29·43	100·00
Frodingham Ironstone Mines (Lord St. Oswald) ...	Dry ...	25·63	1·12	7·35	4·60	20·45	0·93	0·21	0·38		39·33	100·00
	Nat....	23·36	1·02	6·70	4·20	18·64	0·85	0·19	0·35	8·84	35·85	100·00
Midland Ironstone Co.	Dry ...	27·52	—	13·87	9·09	16·08	0·91	0·16	0·32		32·05	100·00
	Nat....	23·31	—	11·75	7·70	13·62	0·77	0·14	0·27	15·31	27·13	100·00
Sheepbridge Iron and Coal Co. ...	Dry ...	28·43	1·10	8·86	—	19·48	—	—	0·32		41·81	100·00
	Nat....	24·45	0·95	7·62	—	16·75	—	—	0·28	14·00	35·95	100·00
Trent Iron and Coal Co.	Dry ...	27·29	1·36	6·59	2·47	24·35	1·41	0·14	0·42		35·97	100·00
	Nat....	23·20	1·16	5·60	2·10	20·70	1·20	0·12	0·35	15·00	30·57	100·00
Walter Scott & Co.	Dry ...	24·83	0·94	7·30	5·05	23·53	—	0·39	0·30		37·66	100·00
	Nat....	23·12	0·87	6·80	4·70	21·91	—	0·36	0·27	6·90	35·07	100·00
Yorkshire Iron and Coal Co. ...	Dry ...	24·40	—	6·60	—	22·18	—	—	—		46·82	100·00
	Nat....	21·28	—	5·76	—	19·34	—	—	—	12·80	40·82	100·00

4. South Lincolnshire, Leicestershire, and Oxfordshire Ironstones (Middle Lias). 1917.

Quarry.	Owner.	—	Iron.	Manganese.	Silica.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.	Moisture.	Difference (Combined H_2O, O, CO_2, etc.).	Total.
Adderbury ...	Cochrane & Co.	Dry ...	33·92	0·16	11·33	7·30	9·24	0·22	0·07	0·32		37·44	100·00
		Nat....	28·63	0·14	9·57	6·16	7·80	0·19	0·06	0·27	15·60	31·58	100·00
Astrop	Alfred Hickman, Ltd. ...	Dry ...	24·91	0·14	9·00	8·77	18·36	1·07	0·07	0·36		37·32	100·00
		Nat....	21·30	0·12	7·70	7·50	15·70	0·92	0·06	0·31	14·50	31·89	100·00
Basic (Eaton) ...	Staveley Coal and Iron Co.	Dry ...	30·82	0·38	12·93	9·09	7·52	0·79	0·06	0·38		38·03	100·00
		Nat....	26·50	0·33	11·12	7·82	6·50	0·68	0·05	0·33	14·00	32·67	100·00
Byfield ...	Northants Ironstone Co. ...	Dry ...	27·78	0·33	13·77	7·50	13·94	0·90	0·12	0·33		35·33	100·00
		Nat....	23·81	0·29	11·80	6·43	11·95	0·78	0·10	0·29	14·31	30·24	100·00
Caythorpe ...	Walter Burke	Dry ...	26·25	0·31	13·64	7·09	15·06	0·68	0·12	0·25		36·60	100·00
		Nat....	23·08	0·27	11·99	6·24	13·24	0·60	0·10	0·22	12·09	32·17	100·00
Eaton	Holwell Iron Co.	Dry ...	32·05	0·34	14·94	9·00	8·00	0·76	0·06	0·39		34·46	100·00
		Nat....	27·25	0·29	12·70	7·65	6·80	0·65	0·05	0·32	15·00	29·29	100·00
Eastwell ...	Staveley Coal and Iron Co.	Dry ...	31·75	0·38	13·43	10·43	10·02	0·88	0·13	0·34		32·64	100·00
		Nat....	26·00	0·31	11·00	8·54	8·20	0·72	0·11	0·28	18·11	26·73	100·00
Harston ...	Stanton Ironworks Co. ...	Dry ...	30·27	0·13	11·32	10·80	12·40	0·52	0·19	0·21		34·16	100·00
		Nat....	25·00	0·11	9·35	8·92	10·25	0·43	0·16	0·18	17·40	28·20	100·00
Milton	Bloxham Ironstone Co. ...	Dry ...	22·44	0·29	12·77	8·26	22·43	0·60	0·04	0·27		32·90	100·00
		Nat....	18·60	0·24	10·59	6·85	18·60	0·50	0·03	0·22	17·10	27·27	100·00
Park Farm ...	Brymbo Steel Co.	Dry ...	37·16	0·40	15·70	11·40	2·60	0·41	0·05	0·16		32·12	100·00
		Nat....	29·90	0·33	12·64	9·18	2·10	0·33	0·04	0·13	19·53	25·82	100·00
Redlands ...	Brymbo Steel Co.	Dry ...	29·65	0·44	11·27	10·77	13·04	0·74	0·07	0·17		33·85	100·00
		Nat....	25·53	0·38	9·70	9·28	11·23	0·64	0·06	0·15	13·90	29·13	100·00
Waltham ...	Staveley Coal and Iron Co.	Dry ...	36·44	0·24	18·26	11·67	2·21	0·66	0·18	0·36		29·98	100·00
		Nat....	26·85	0·18	13·45	8·60	1·63	0·49	0·13	0·27	26·32	22·08	100·00

5. Northamptonshire and Rutlandshire Ironstones (Inferior Oolite). 1917.

Quarry or Mine.	Owner.	—	Iron.	Manganese.	Silica.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.	Moisture.	Difference (O, CO_2, Combined H_2O, etc.).	Total.
Brixworth ...	Brixworth Ironstone Co. ...	Dry ...	35·00	0·31	21·36	9·89	3·37	0·67	0·08	0·86		28·46	100·00
		Nat....	31·02	0·28	18·90	8·75	2·98	0·59	0·07	0·76	11·50	25·15	100·00
Buckminster ...	Holwell Iron Co.	Dry ...	40·00	0·31	18·55	7·42	1·04	0·38	0·06	0·66		31·58	100·00
		Nat....	33·30	0·26	15·46	6·18	0·87	0·32	0·05	0·55	16·67	26·34	100·00
Burton ...	Staveley Coal and Iron Co.	Dry ...	40·85	0·30	21·33	6·48	1·95	0·30	0·09	0·64		28·06	100·00
		Nat....	35·17	0·26	18·37	5·58	1·68	0·26	0·08	0·55	13·90	24·15	100·00
Corby	Lloyds Ironstone Co. ...	Dry ...	40·50	0·30	12·88	7·73	3·80	0·60	0·14	0·66		33·39	100·00
		Nat....	33·48	0·25	10·66	6·40	3·15	0·50	0·12	0·55	17·25	27·64	100·00
Cottesmore ...	Sheepbridge Coal and Iron Co.	Dry ...	35·79	0·29	21·50	12·29	4·00	0·73	0·02	0·59		24·79	100·00
		Nat....	29·45	0·24	17·70	10·12	3·30	0·60	0·02	0·49	17·70	20·38	100·00
Cranford ...	Staveley Coal and Iron Co.	Dry ...	39·40	0·22	20·81	5·98	2·03	0·24	0·13	0·52		30·67	100·00
		Nat....	34·41	0·19	18·21	5·24	1·78	0·21	0·12	0·46	12·52	26·86	100·00
Cranford St. John	Claycross Co.	Dry ...	35·10	—	27·51	—	2·51	—	—	—		34·88	100·00
		Nat....	31·07	—	24·35	—	2·20	—	—	—	11·50	30·88	100·00
Desboro' ...	Sheepbridge Coal and Iron Co.	Dry ...	34·53	0·23	16·93	7·28	6·36	0·44	0·05	0·58		33·60	100·00
		Nat....	29·40	0·20	14·42	6·20	5·42	0·37	0·04	0·49	14·85	28·61	100·00
Desboro' ...	Desboro' Co-operative Society	Dry ...	39·61	0·12	17·06	8·65	3·86	0·19	0·08	0·61		29·82	100·00
		Nat....	32·51	0·10	14·00	7·10	3·17	0·16	0·07	0·50	17·93	24·46	100·00
Earlsbarton ...	Stanton Ironstone Co. ...	Dry ...	34·00	0·32	20·20	12·10	0·49	0·46	0·21	0·71		31·51	100·00
		Nat....	28·69	0·27	17·05	10·21	0·42	0·39	0·17	0·60	15·60	26·60	100·00

Easton ...	North Lincs Iron Co. ...	Dry ...	35·47	0·19	29·58	5·53	1·49	0·72	0·06	0·59		26·37	100·00
		Nat....	31·02	0·17	25·88	4·84	1·30	0·63	0·05	0·52	12·57	23·02	100·00
Finedon ...	C. Barlow	Dry ...	38·87	0·46	16·25	8·30	3·08	0·86	0·18	0·60		31·40	100·00
		Nat....	33·97	0·40	14·20	7·25	2·69	0·75	0·16	0·53	12·61	27·44	100·00
Glendon ...	James Pain, Ltd.	Dry ...	37·96	0·36	16·70	9·02	3·24	0·74	0·23	0·88		30·87	100·00
		Nat....	31·64	0·30	13·92	7·51	2·70	0·62	0·19	0·74	16·65	25·73	100·00
Greetwell ...	Mid-Lincs Iron Co. ...	Dry ...	37·92	0·22	18·78	7·04	3·78	0·87	0·16	0·56		30·66	100·00
		Nat....	33·81	0·20	16·75	6·28	3·37	0·72	0·15	0·50	10·85	27·37	100·00
Kettering ...	Kettering Iron and Coal Co.	Dry ...	36·53	—	11·54	7·84	7·18	—	—	—		36·91	100·00
		Nat....	32·88	—	10·39	7·06	6·46	—	—	—	10·00	33·21	100·00
Lamport ...	Staveley Coal and Iron Co.	Dry ...	40·39	—	18·27	4·79	4·08	—	0·38	0·96		31·12	100·00
		Nat....	33·82	—	15·30	4·01	3·42	—	0·32	0·81	16·27	26·05	100·00
Leadenham ...	Major George Dove ...	Dry ...	34·52	—	21·62	—	4·08	—	—	—		39·78	100·00
		Nat....	30·50	—	19·10	—	3·61	—	—	—	11·64	35·15	100·00
Loddington ...	Staveley Coal and Iron Co.	Dry ...	37·87	0·11	15·32	6·23	4·66	0·07	0·09	0·69		34·96	100·00
		Nat....	31·78	0·09	12·86	5·23	3·91	0·06	0·08	0·58	16·08	23·33	100·00
Market Overton	James Pain, Ltd.	Dry ...	40·80	0·44	17·97	2·32	1·72	0·68	0·08	0·63		35·36	100·00
		Nat....	34·29	0·37	15·10	1·95	1·45	0·57	0·07	0·53	15·95	29·72	100·00
Uppingham ...	James Pain, Ltd.	Dry ...	35·46	0·14	20·15	8·27	4·04	0·99	0·09	0·70		30·16	100·00
		Nat....	30·00	0·12	17·05	7·00	3·42	0·84	0·08	0·59	15·40	25·50	100·00
Wellingborough	James Pain, Ltd.	Dry ...	37·46	0·27	16·32	8·97	2·55	0·59	0·06	0·87		32·91	100·00
		Nat....	30·30	0·22	13·20	7·26	2·06	0·48	0·05	0·70	19·12	26·61	100·00
Wellingborough	J. Clarke	Dry ...	38·25	0·20	18·56	—	1·16	0·04	0·04	0·72		41·03	100·00
		Nat....	31·98	0·17	15·52	—	0·97	0·03	0·03	0·60	16·40	34·30	100·00
Whiston ...	Whiston Ironstone Co. ...	Dry ...	38·27	0·26	17·34	5·23	3·40	0·27	0·05	0·75		34·26	100·00
		Nat....	34·22	0·23	15·50	4·68	3·04	0·33	0·04	0·63	10·60	30·73	100·00

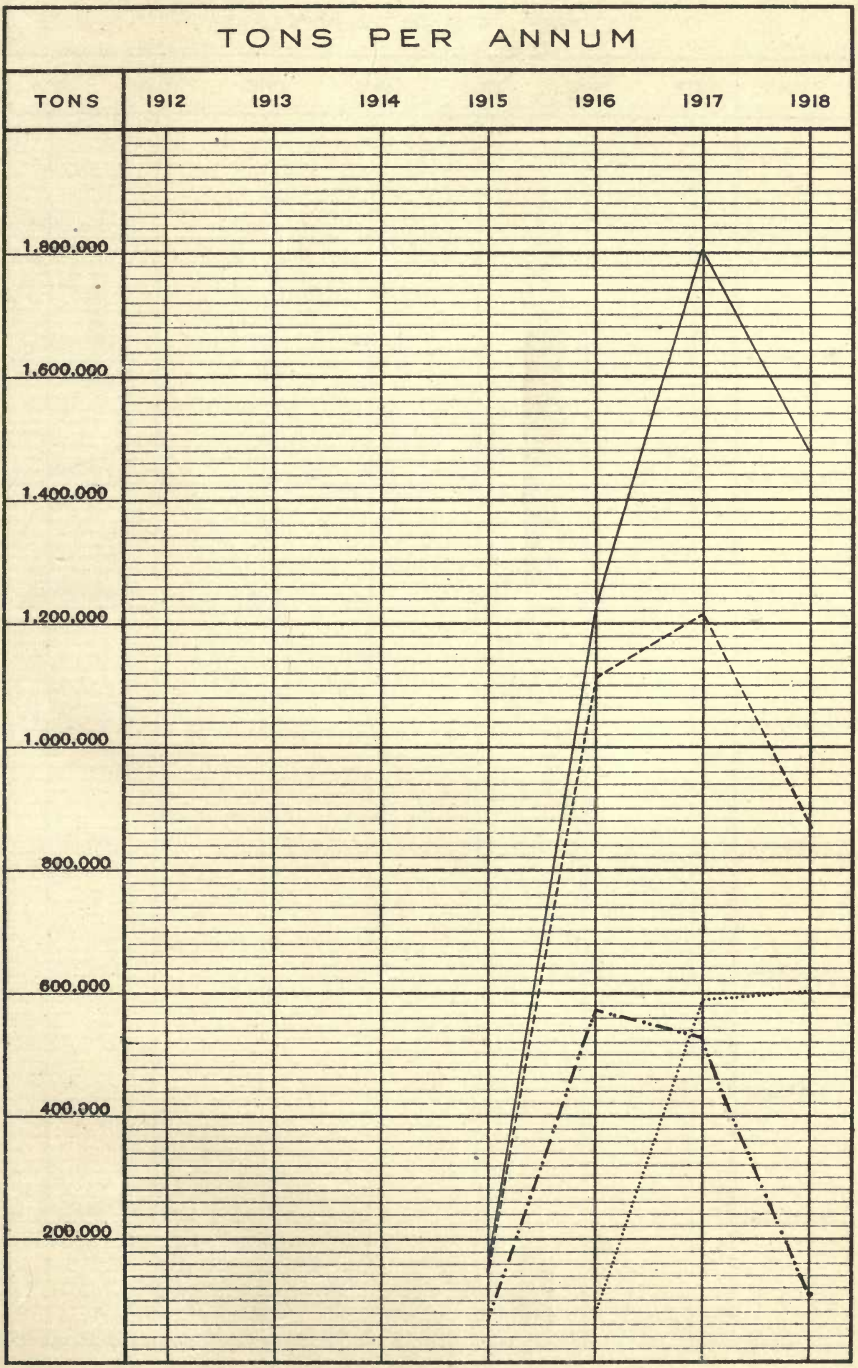
APPENDIX II.

Graphs showing the Production during the war period of Shell Steel, Steel Ingots and Castings, Acid Steel, Basic Steel, Total Pig Iron, Hematite Pig Iron, Basic Pig Iron, Forge and Foundry Iron, Ferro-Alloys, Iron Ore, Manganese Ore and Metallurgical Coke.

Also the Imports into the United Kingdom of Iron Ore and Manganese Ore ; and the Consumption in the United Kingdom of Iron Ore, Manganese Ore, and Metallurgical Coke.

DELIVERIES OF SHELL STEEL

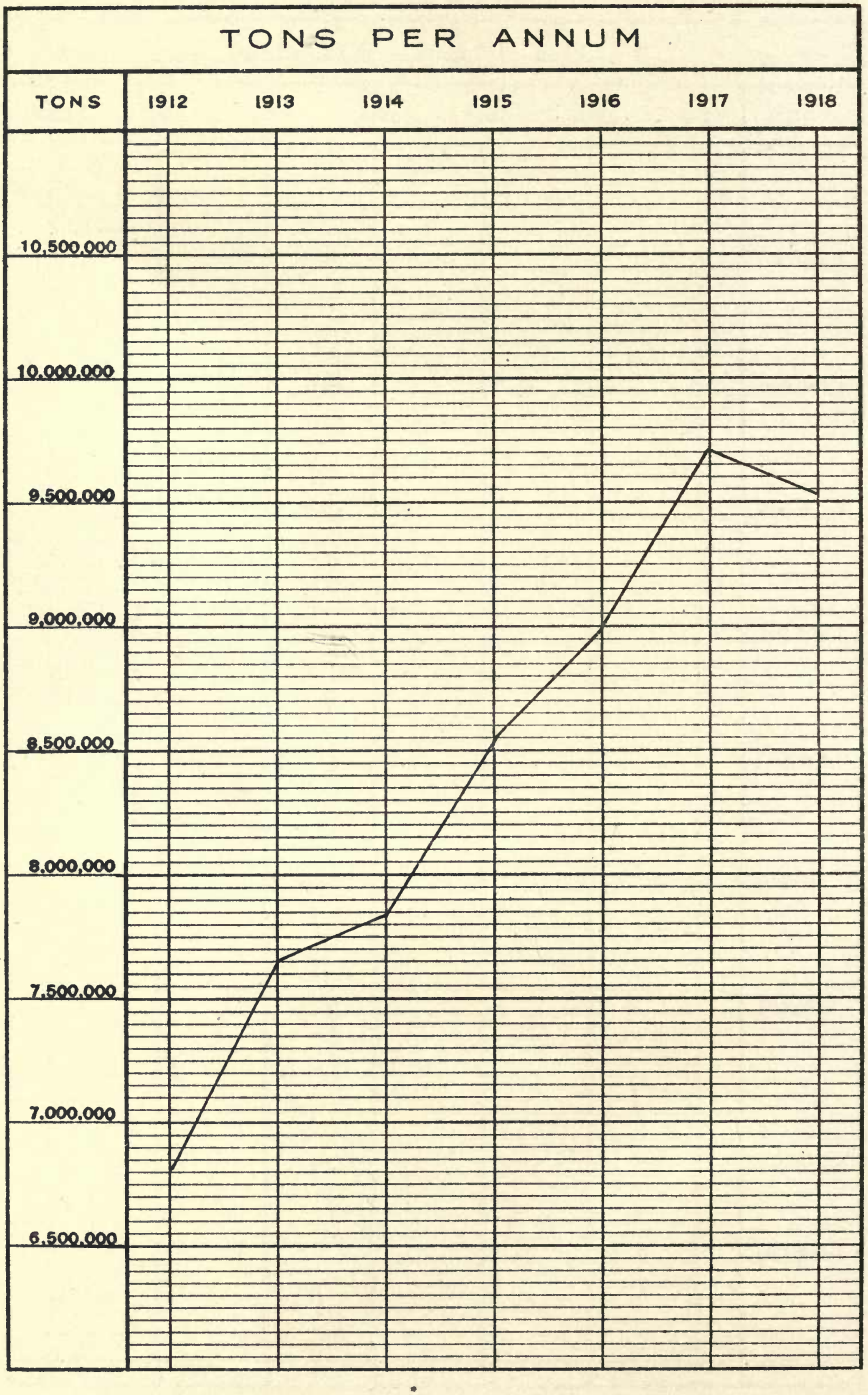
Total deliveries in Great Britain ———————
Deliveries in Great Britain from British Manufacturers – – – – – – – – – – –
Imports to Great Britain from America .....
Deliveries to Allies ··—··—··—··—··—



Iron and Steel Industry : F. H. Hatch.

STEEL INGOTS AND CASTINGS

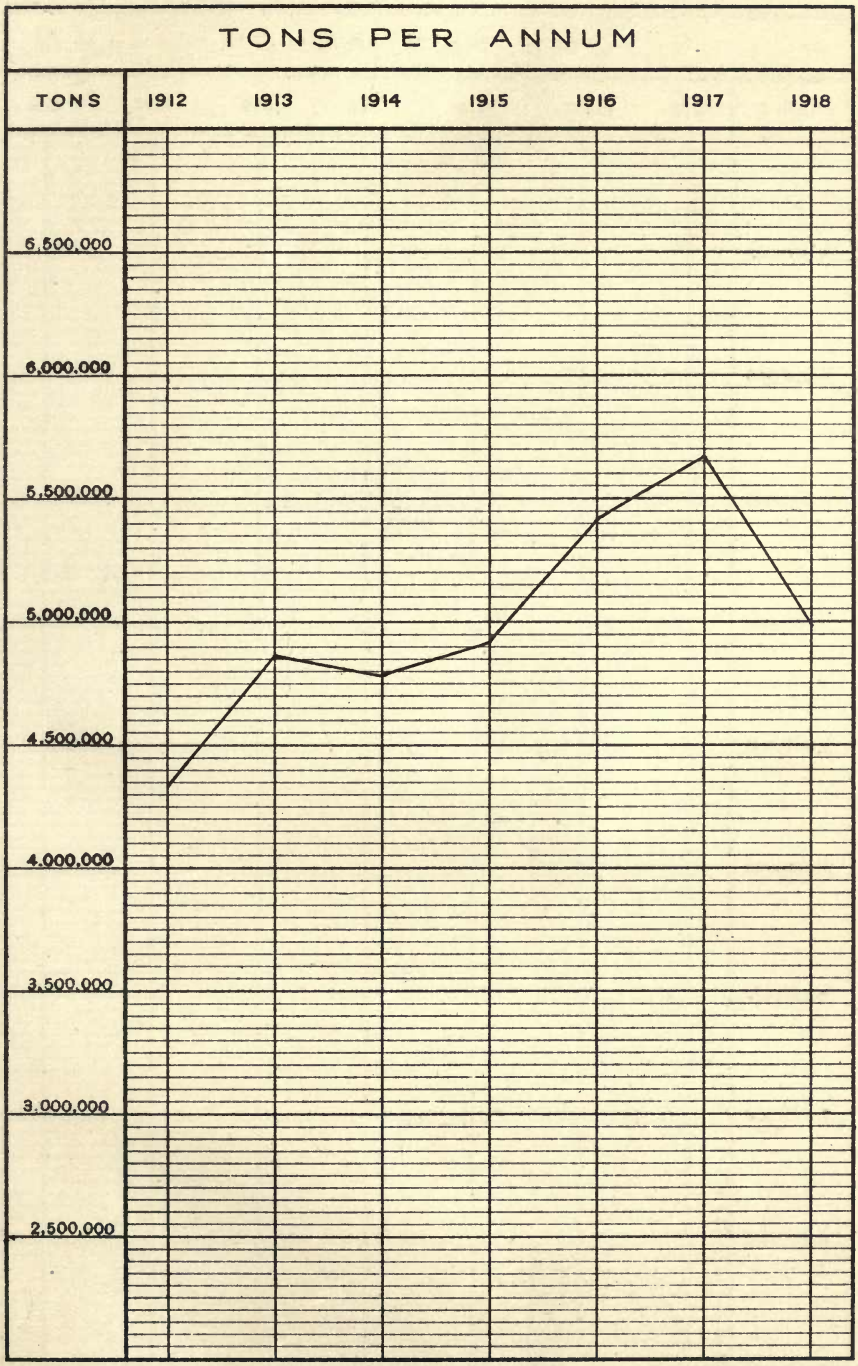
Total production in the United Kingdom



Iron and Steel Industry : F. H. Hatch.

ACID STEEL

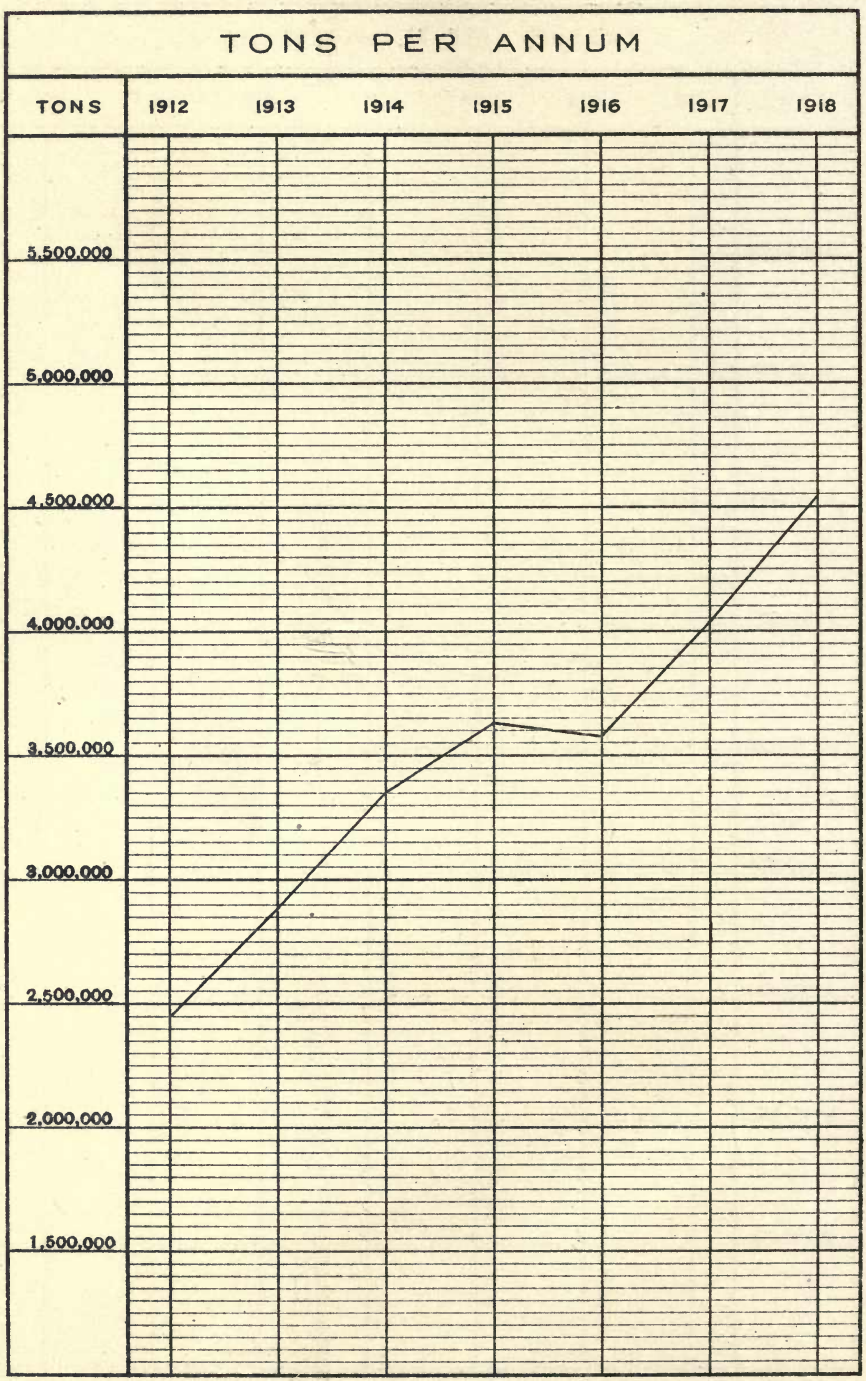
Production in the United Kingdom



Iron and Steel Industry : F. H. Hatch.

BASIC STEEL

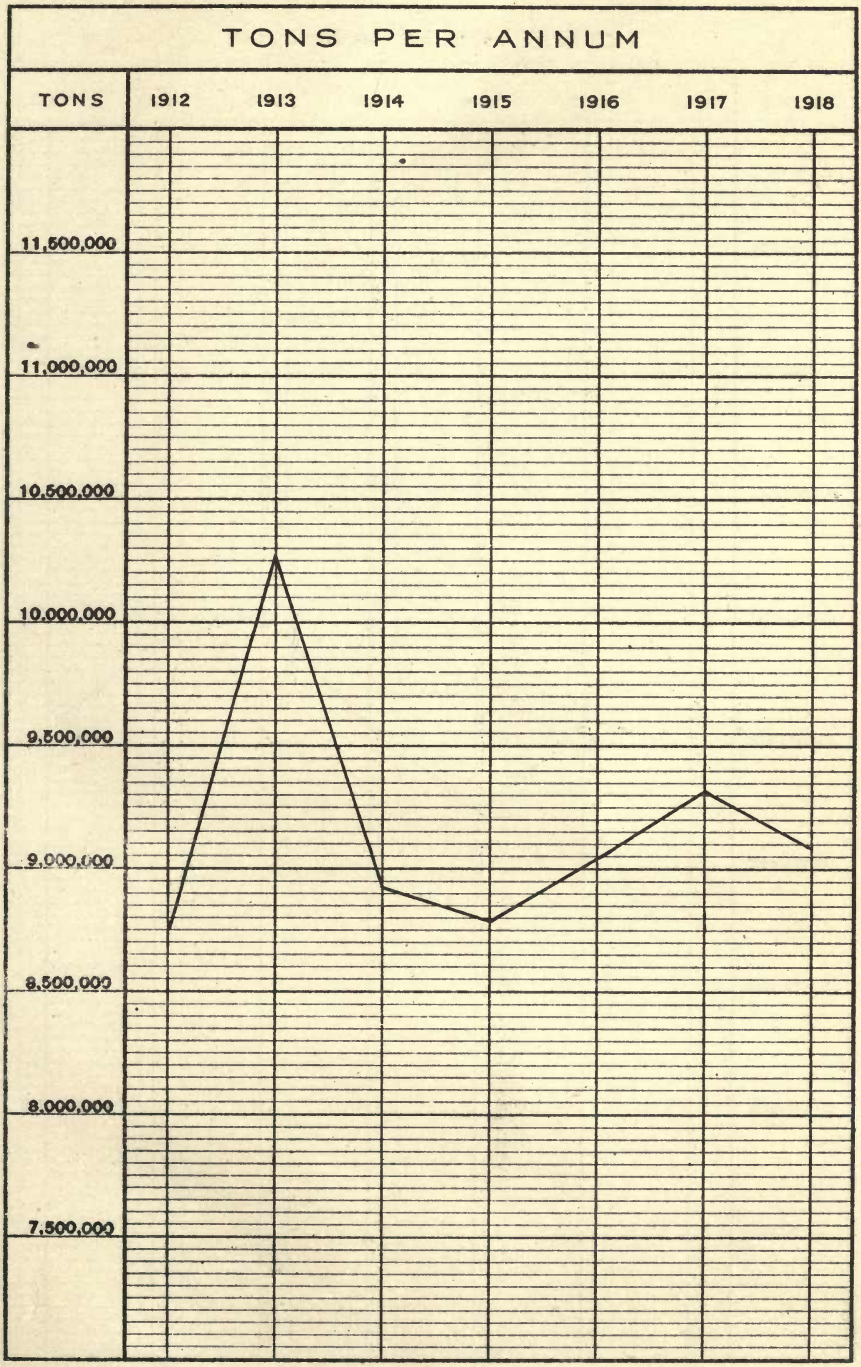
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

PIG IRON

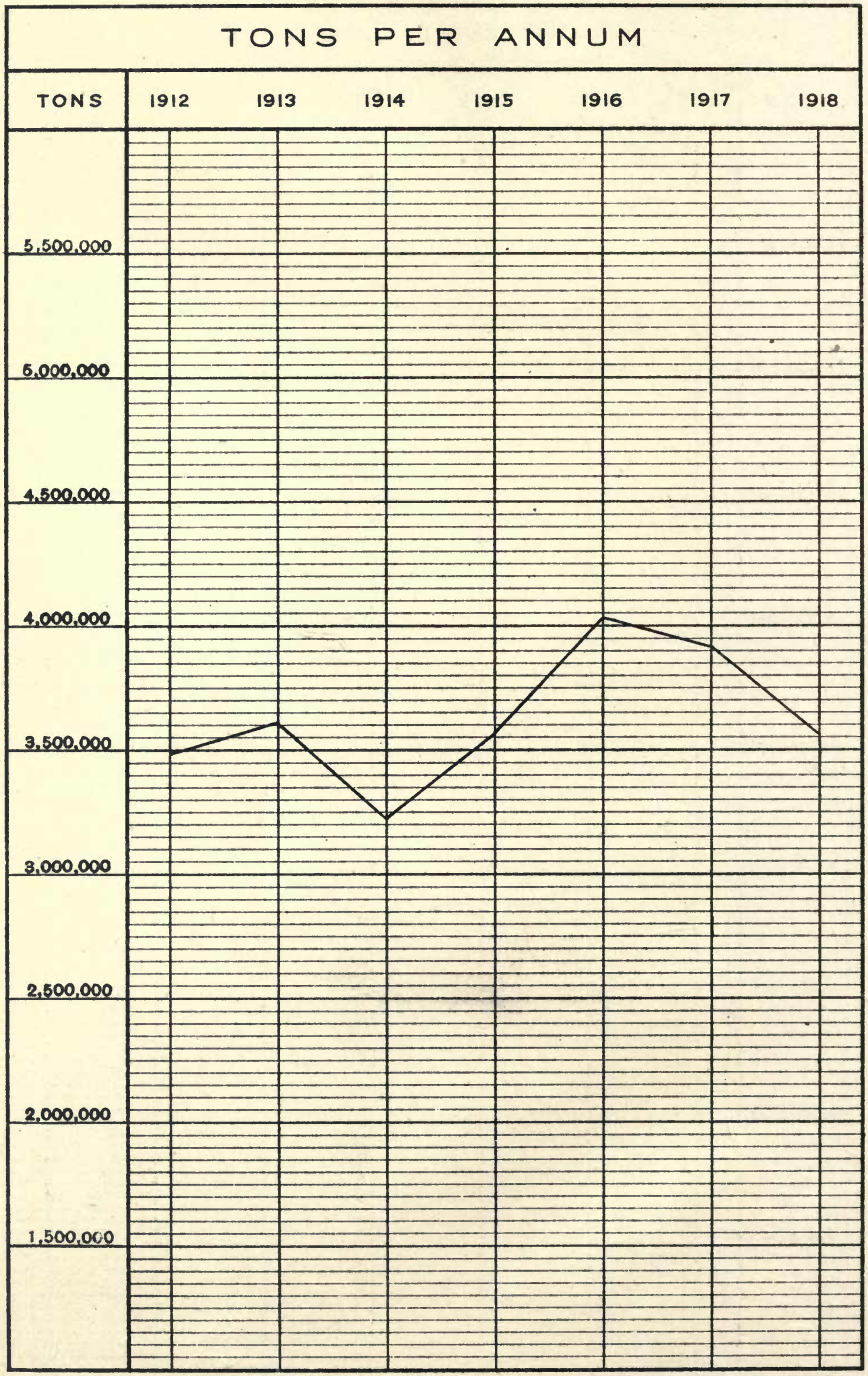
Total production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

HEMATITE PIG IRON

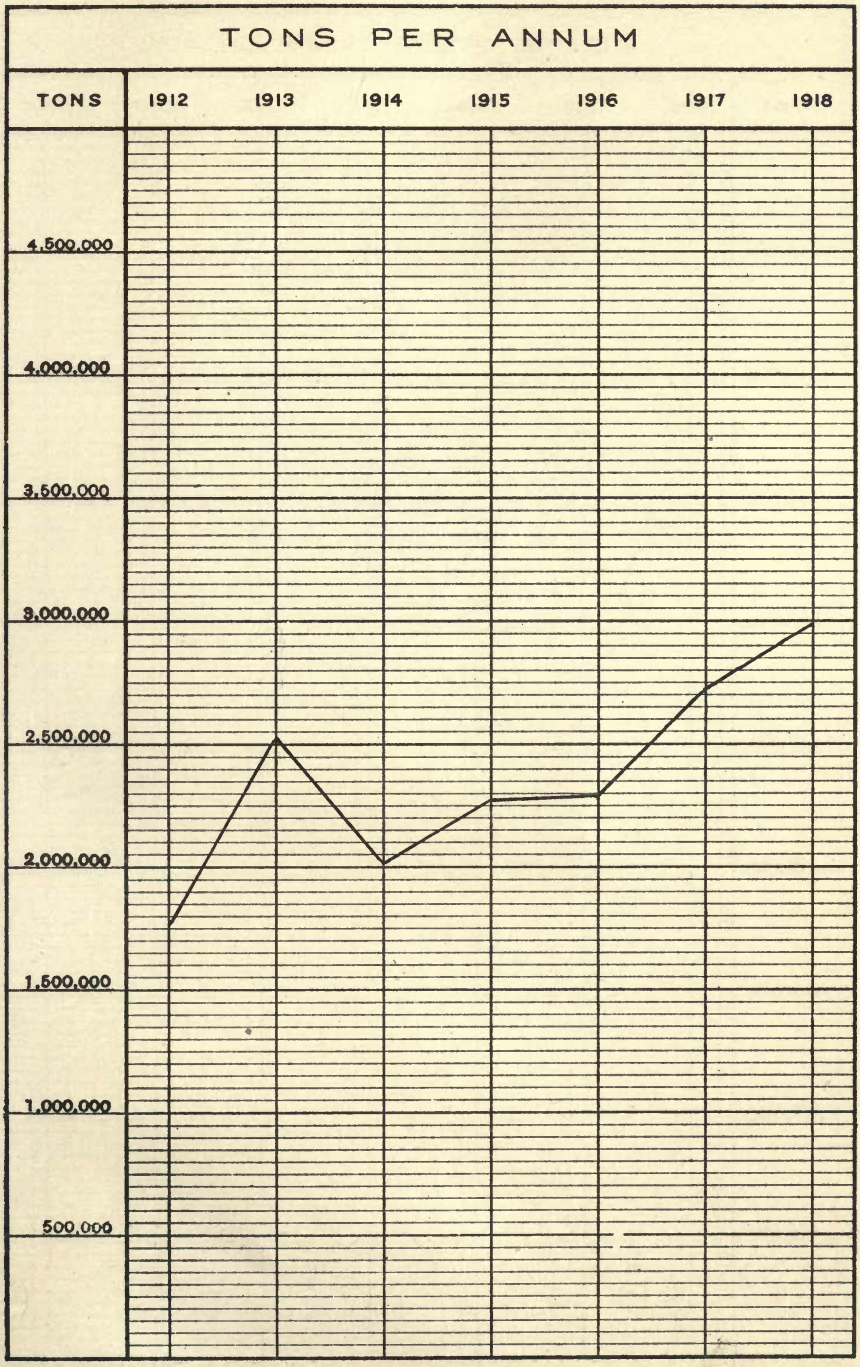
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

BASIC PIG IRON

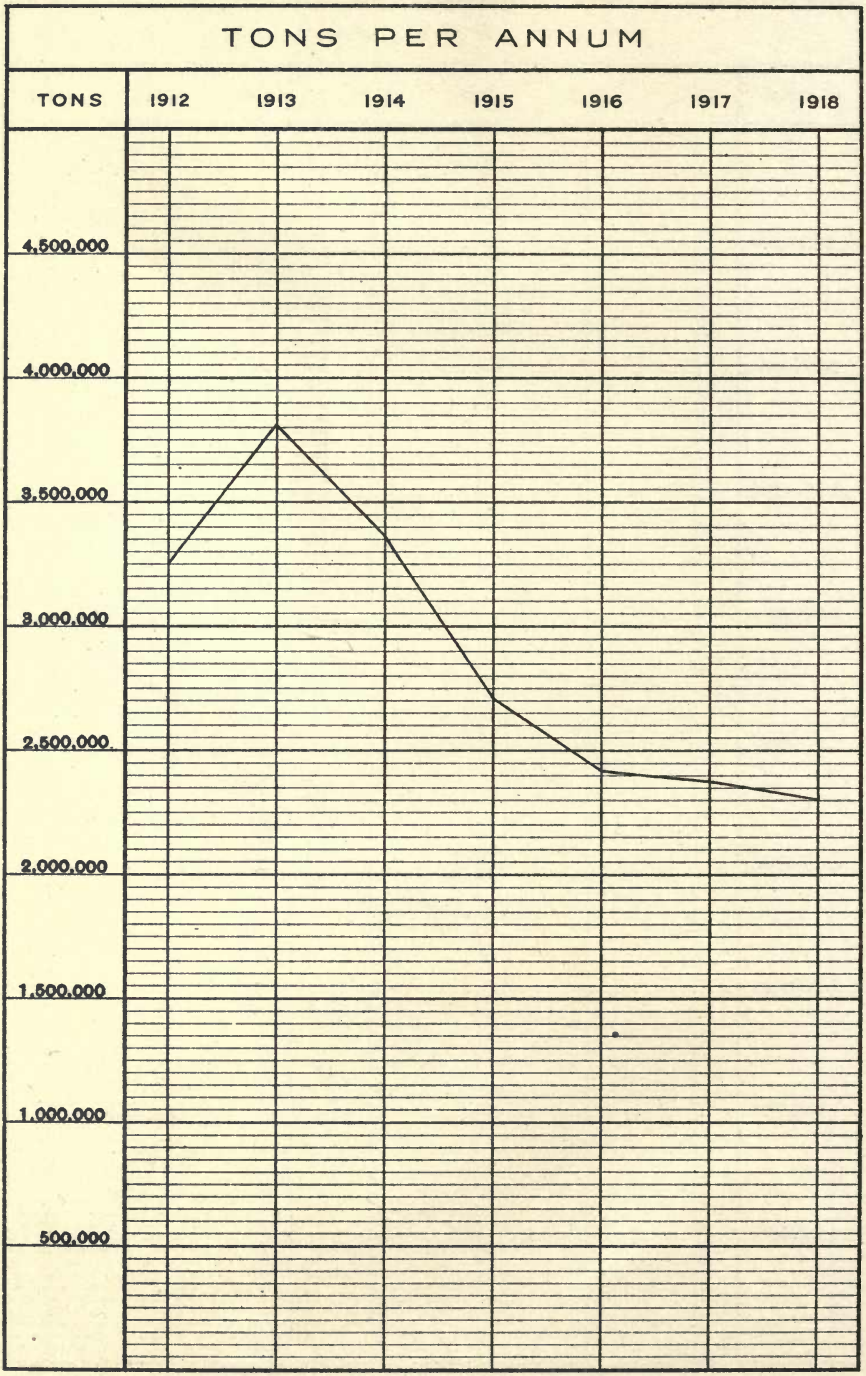
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

FORGE AND FOUNDRY IRON

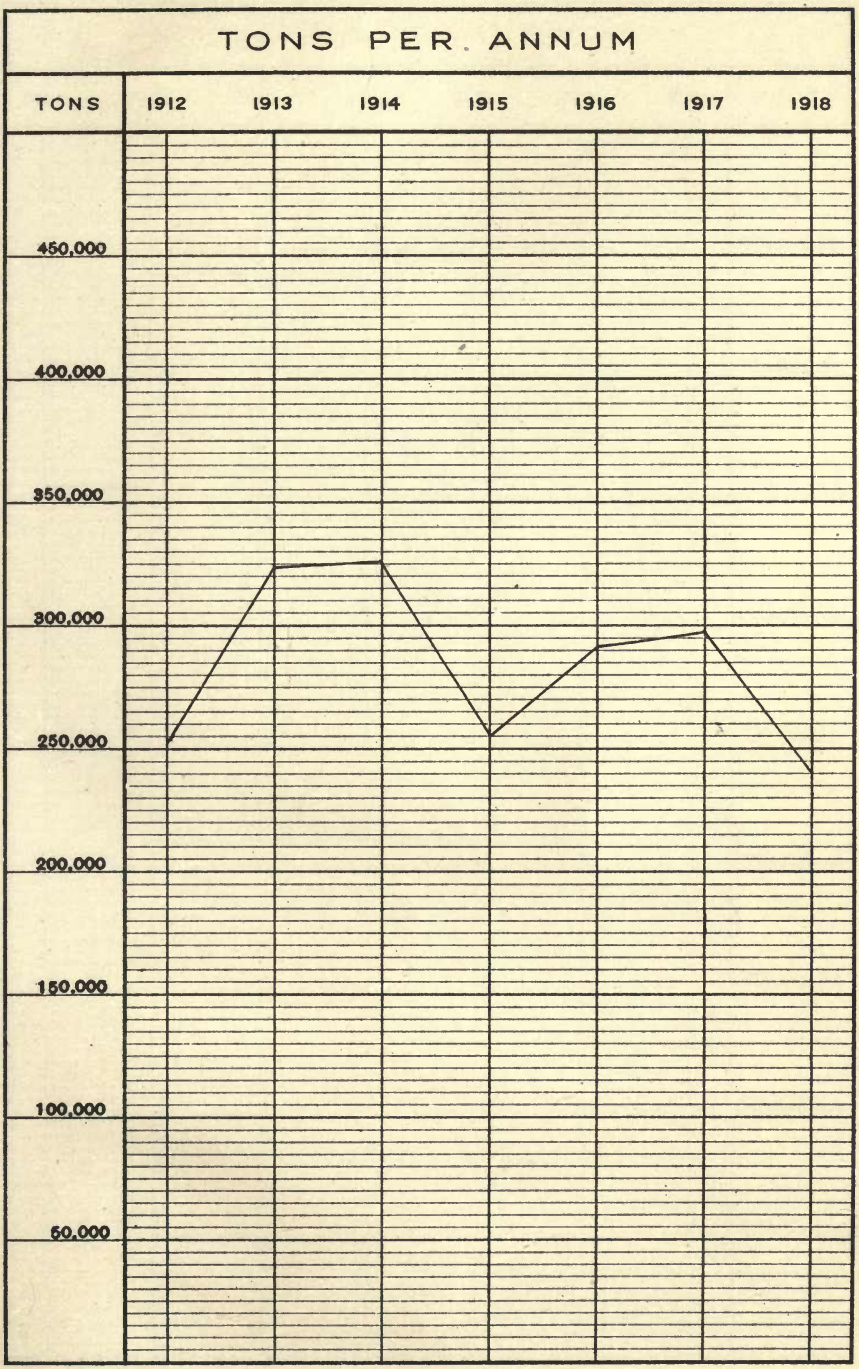
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

FERRO-ALLOYS

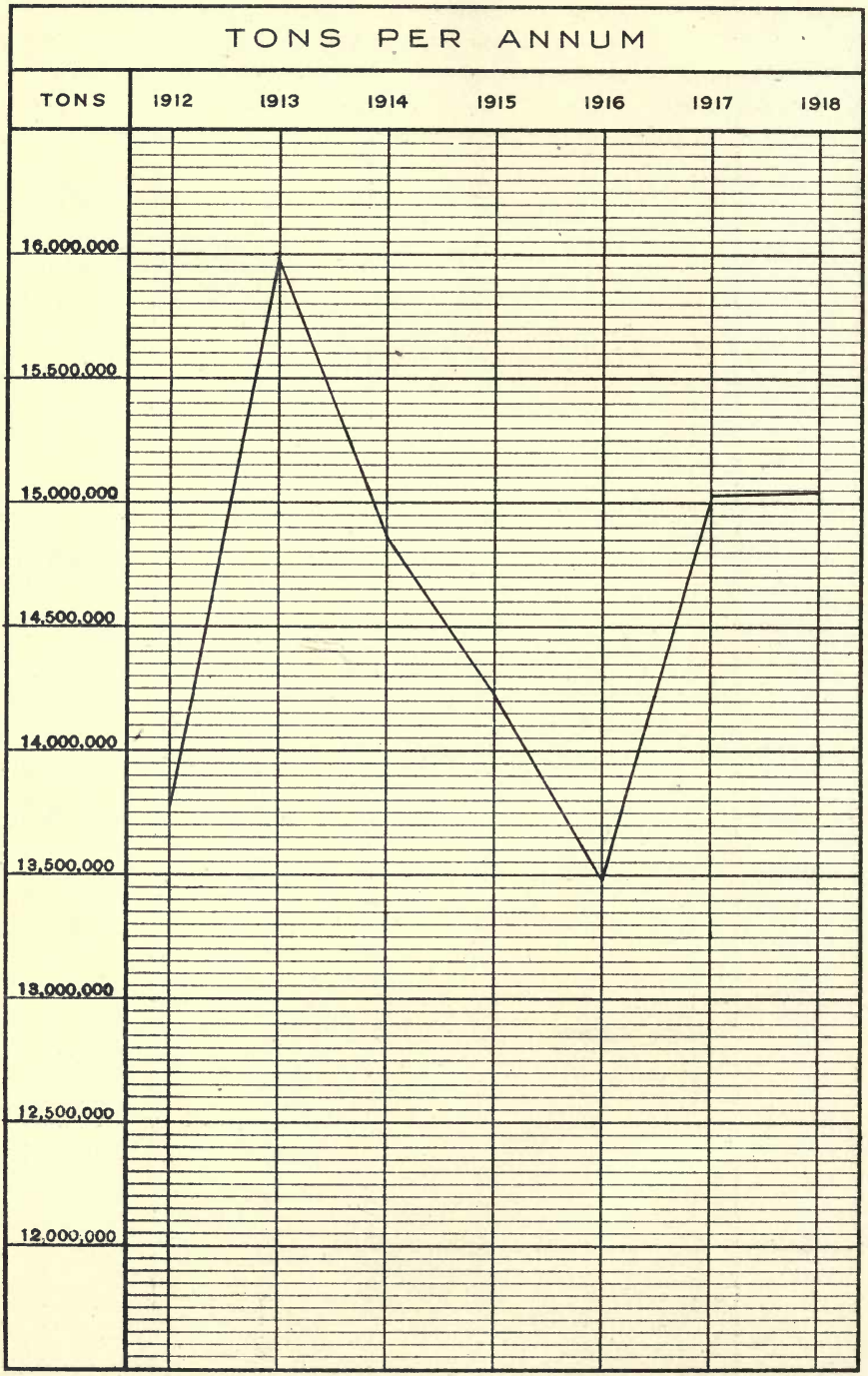
Production in the United Kingdom



Iron and Steel Industry : F. H. Hatch.

IRON ORE

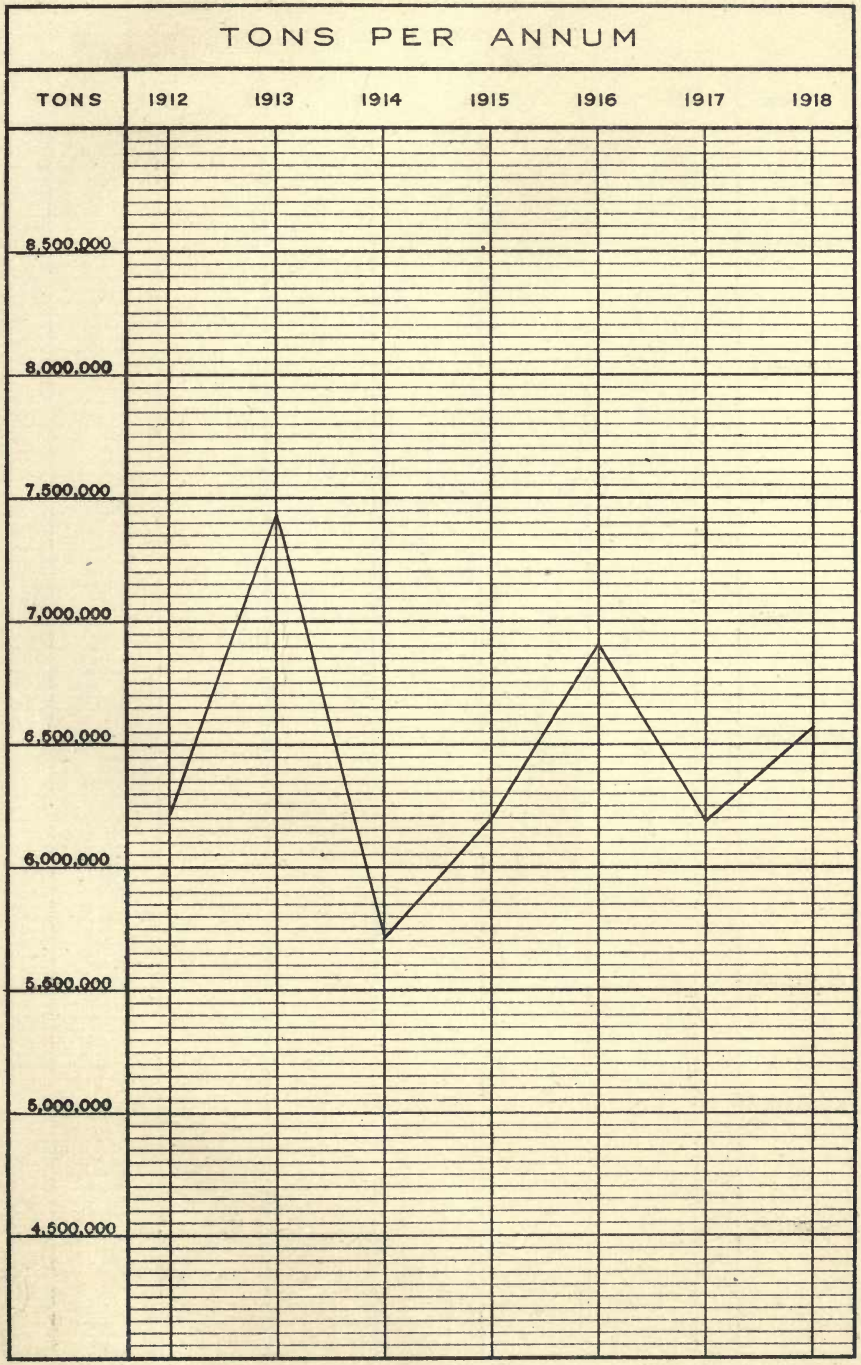
Total production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

IRON ORE

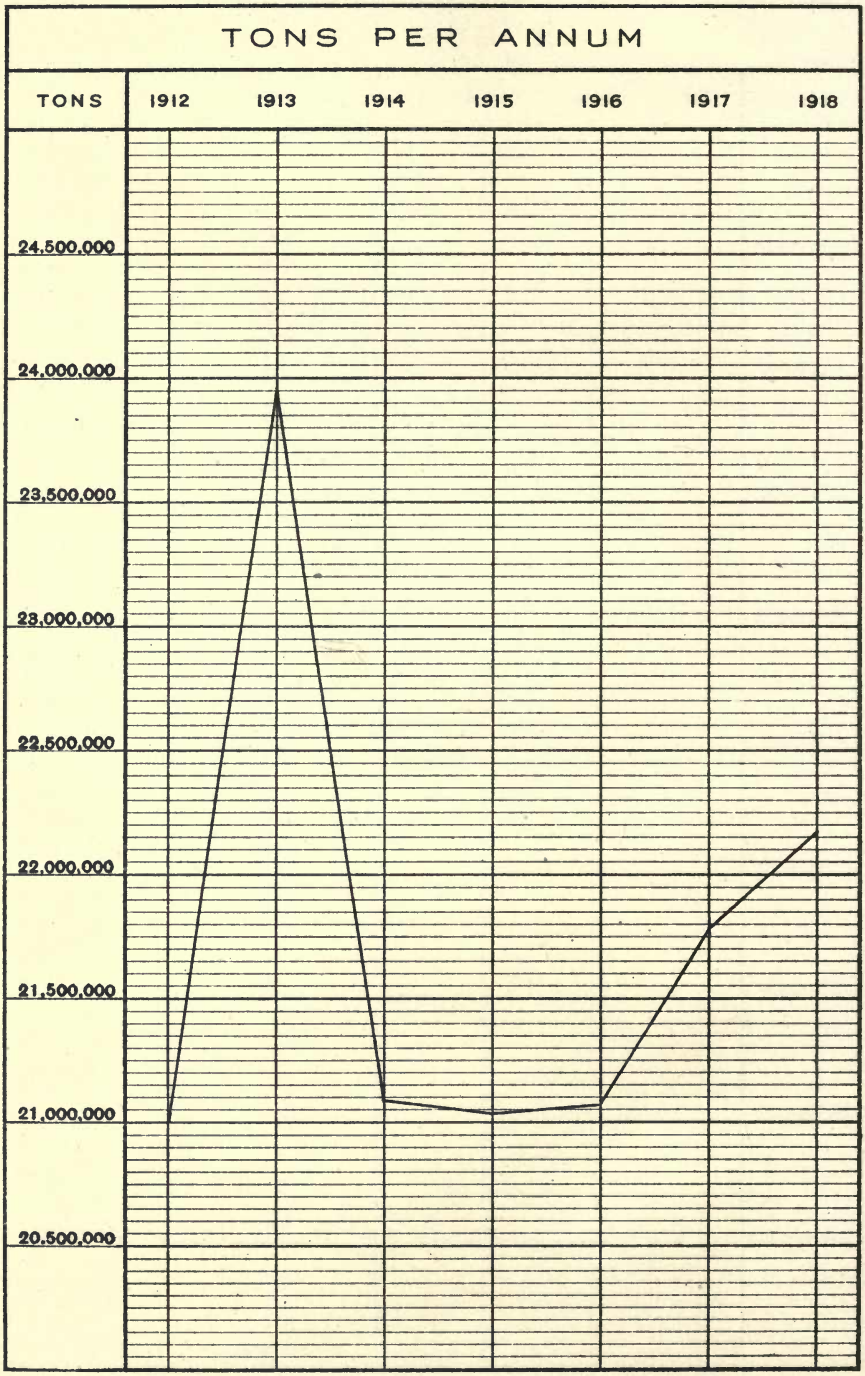
Imports into the United Kingdom



Iron and Steel Industry : F. H. Hatch.

IRON ORE

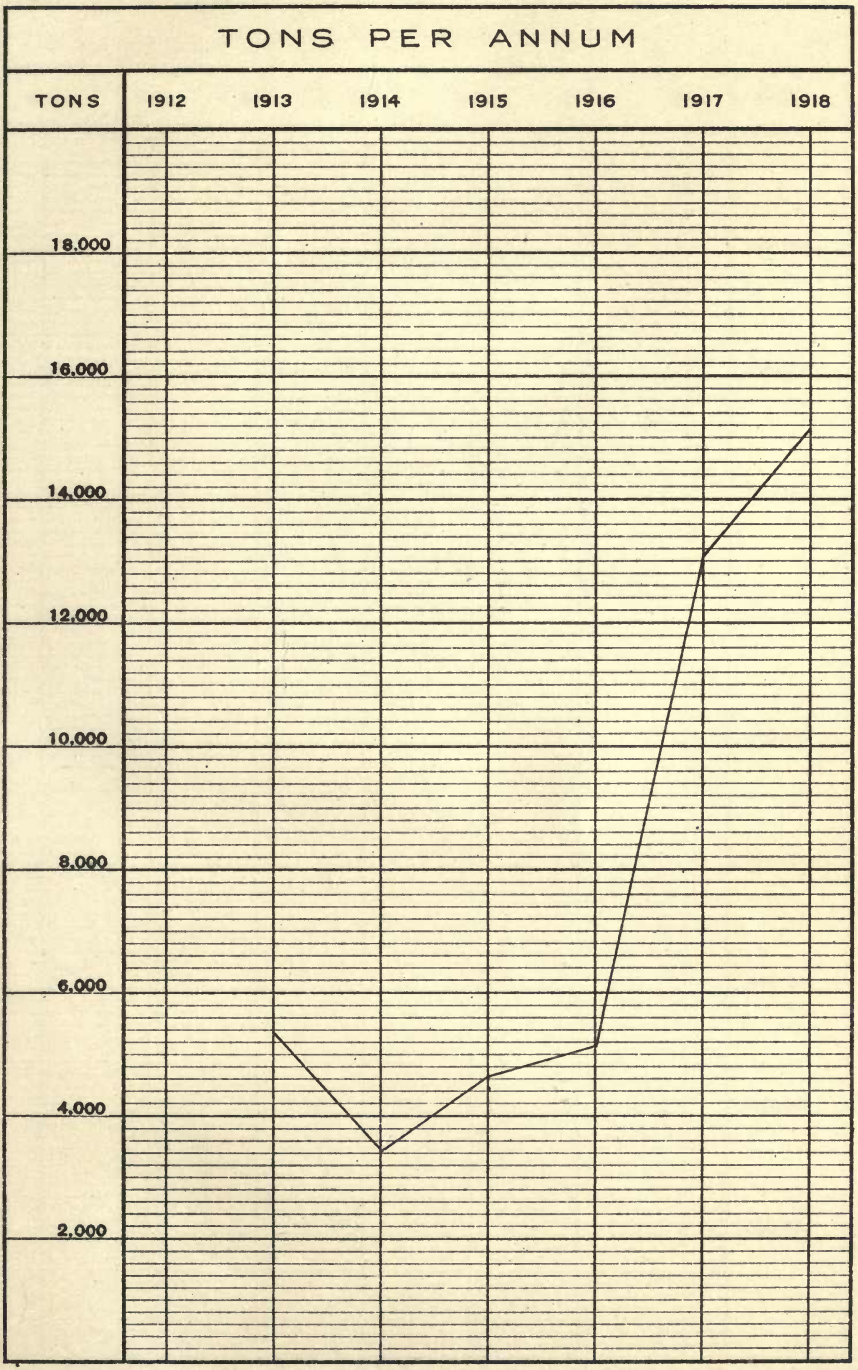
Consumption in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

MANGANESE ORE

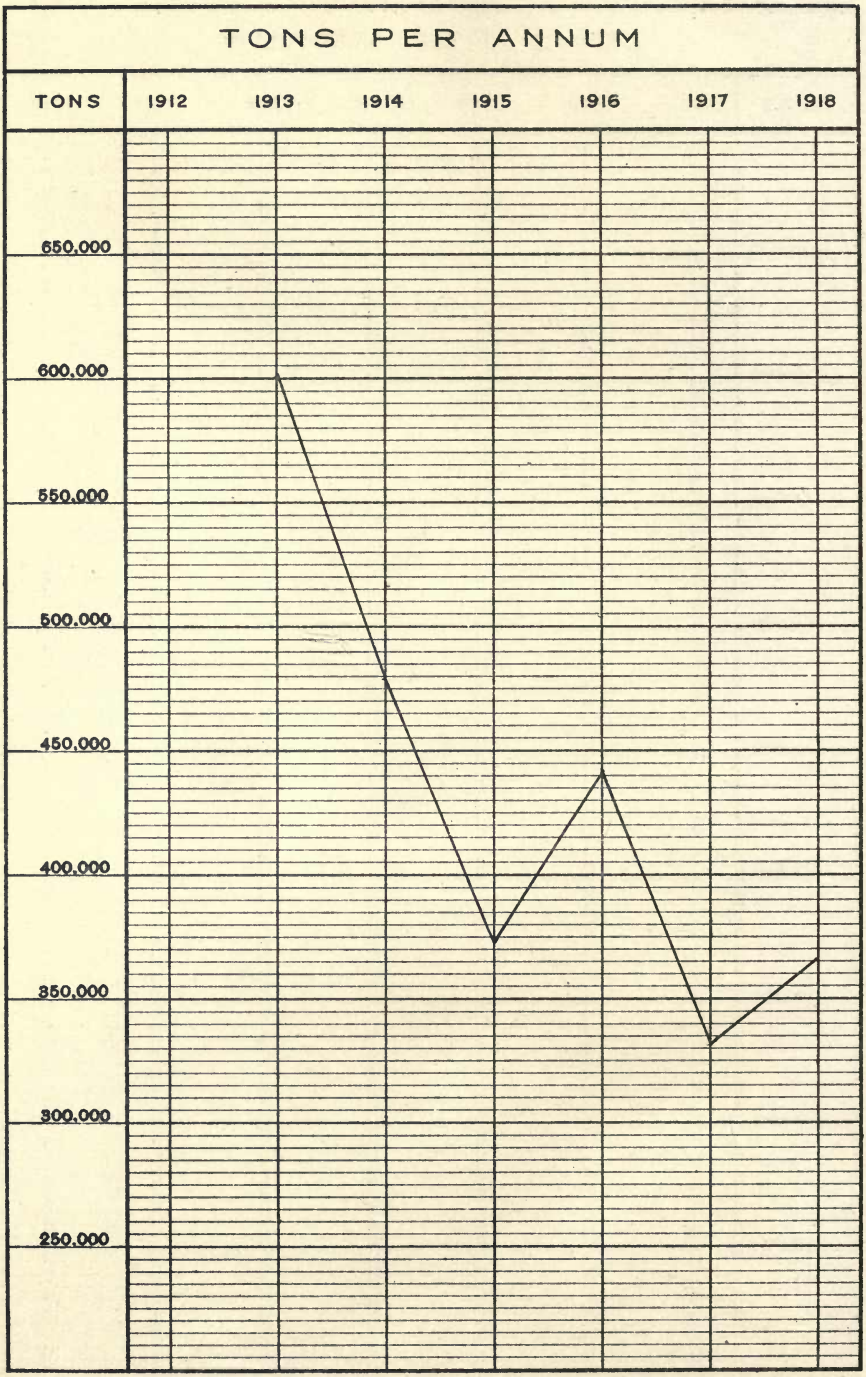
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

MANGANESE ORE

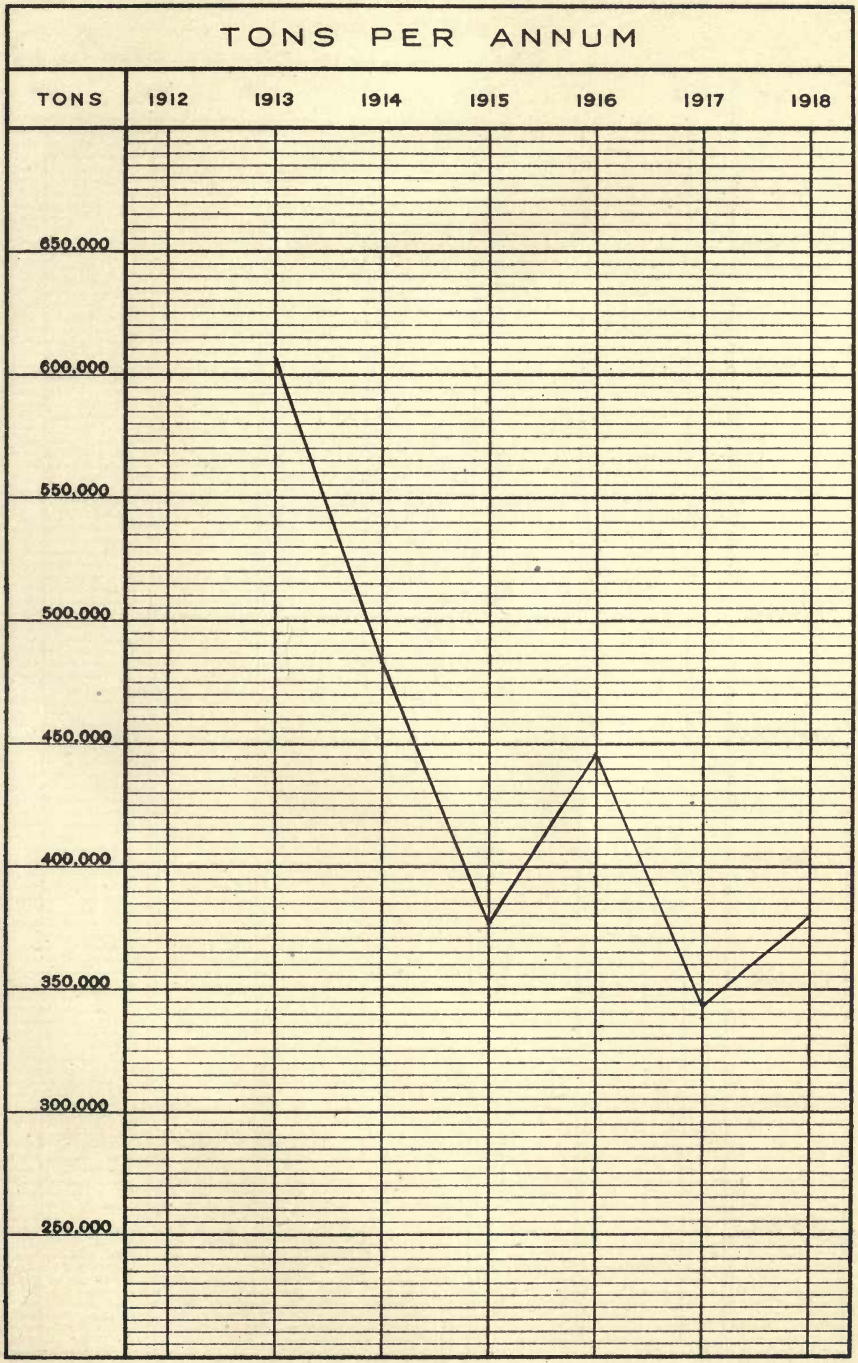
Imports into the United Kingdom



Iron and Steel Industry: F. H. Hatch.

MANGANESE ORE

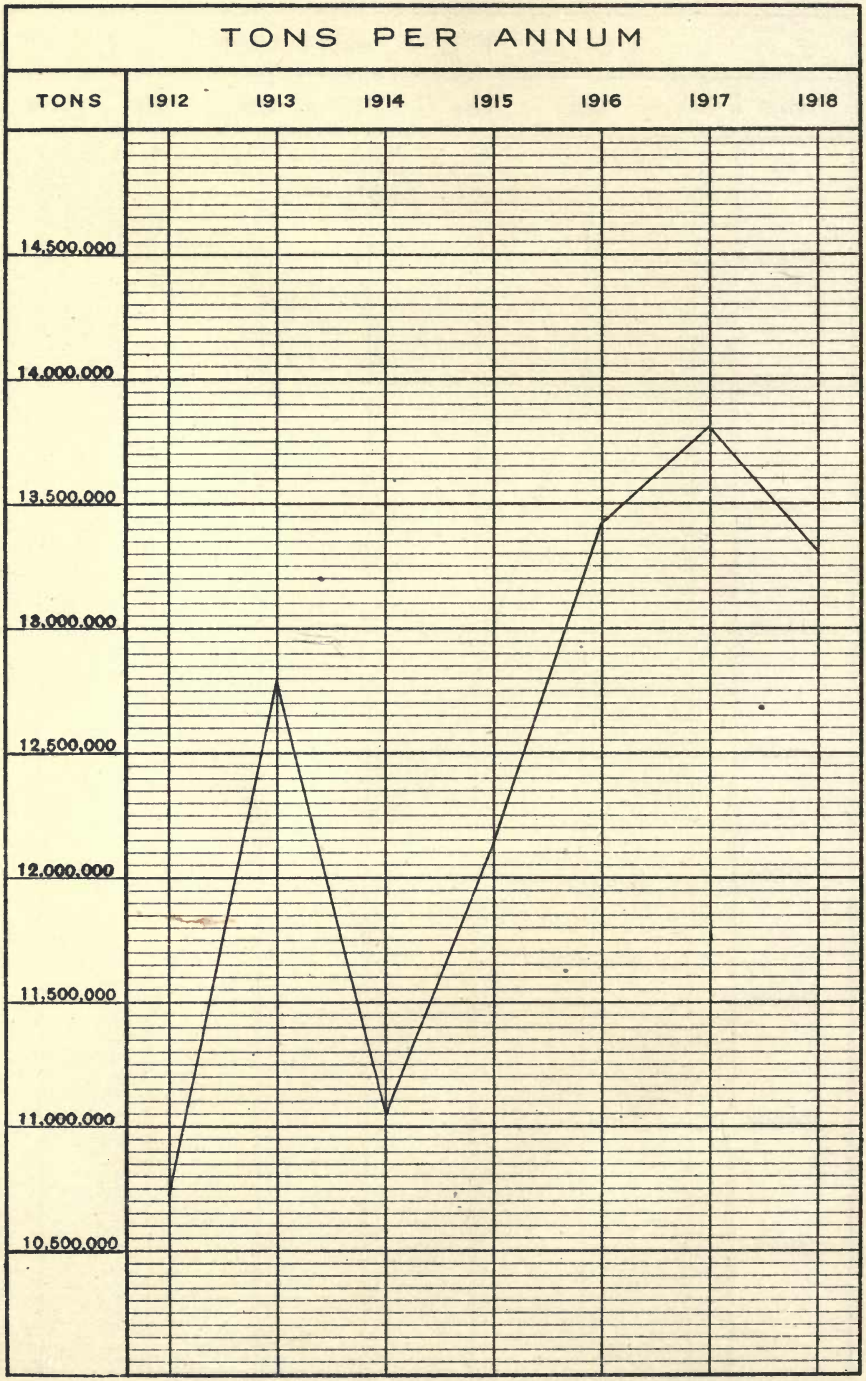
Consumption in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

METALLURGICAL COKE

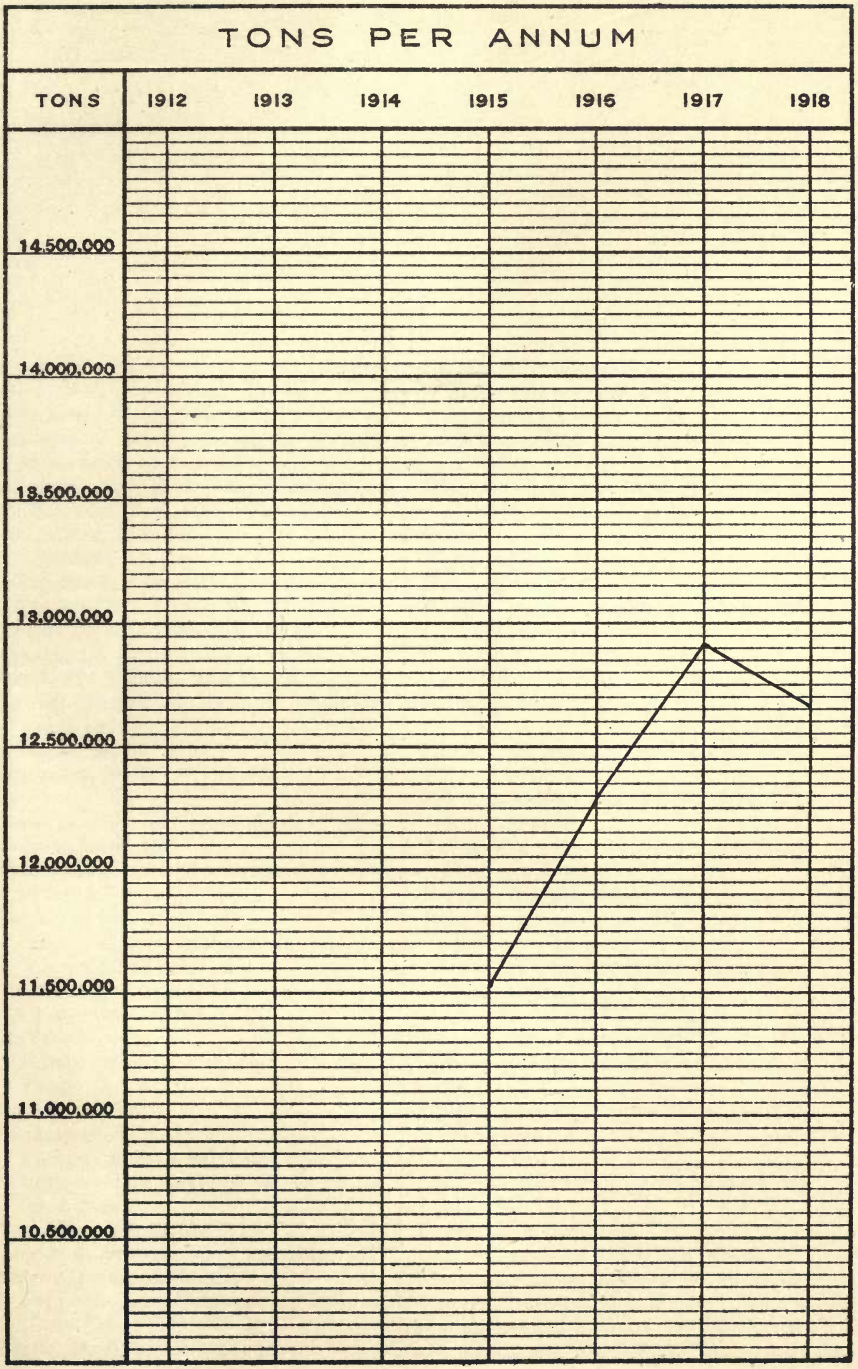
Production in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

METALLURGICAL COKE

Consumption in the United Kingdom



Iron and Steel Industry: F. H. Hatch.

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